ARMY RESEARCH LABORATORY

Volume II: Compendium of Abstracts

by ARL Summer Student Research Symposium

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Volume II: Compendium of Abstracts

ARL Summer Student Research Symposium

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14. ABSTRACT

The ARL Summer Student Research Symposium is an ARL Director's Award Program for all the students participating in various summer scholarship and contract activities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

All college undergraduate and graduate students receiving research appointments and conducting summer studies at ARL are automatically enrolled in the symposium program. As an integral part of their summer study, all students are required to write a paper on their work which summarizes their major activity and its end product.

The program is conducted on two separate competitive levels: undergraduate and graduate. The format of the paper in both levels is the same. However, the evaluation will take into consideration the difference in the academic level of the students.

All students submitted their research paper for directorate review. Directorate judging panels selected two papers from each competition category for the laboratory-wide competition at the Summer Student Symposium on 11 August 2011.

Students selected by their directorate for competition participated in the one-day Summer Student Symposium on 11 August 2011. At the symposium the students presented their papers to the ARL Director and an ARL Fellows panel.

This volume of the Summer Student Symposium Proceedings contains the abstracts for all papers prepared for the Summer Student Symposium Program.

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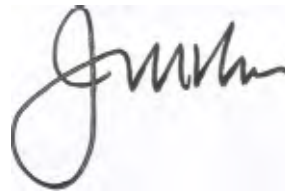| 16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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Contents

Director's Foreword

The U.S. Army Research Laboratory (ARL) mission is to ―Povide innovative science, technology, and analyses to enable full spectrum operations." As the Army's corporate laboratory, we provide the technological underpinnings critical to providing capabilities required by our current and future Soldiers.

Our nation is projected to experience a shortage of scientists and engineers. ARL recognizes the criticality of intellectual capital in generating capabilities for the Army. As the Army's corporate laboratory, addressing the projected shortfall is a key responsibility for us. We have, therefore, identified the nation's next generation of scientists and engineers as a key community of interest and have generated a robust educational outreach program to strengthen and support them. We have achieved many successes with this community. We believe that the breadth and depth of our outreach programs will have a significant positive effect on the participants, facilitating their journey toward becoming this Nation's next generation of scientists and engineers.

A fundamental component of our outreach program is to provide students research experiences at ARL. During the summer of 2011, we supported research experiences at ARL for over 100 undergraduate and graduate students. Each of these students writes a paper describing the results of the work they performed while at ARL. All of the papers were of high quality, but only a few could be presented at our student symposium. The abstracts for all papers prepared this summer are contained in this volume of the proceedings and they indicate that there were many excellent research projects with outstanding results. It is unfortunate that there was not enough time for us to have all of the papers presented. We would have enjoyed hearing them all.

We are very pleased to have hosted this outstanding group of students for the summer. It is our hope that they will continue their pursuit of technical degrees and will someday assist us in providing critical technologies for our Soldiers.

Introduction

The ARL Summer Student Research Symposium is an ARL Director's Award Program for all the students participating in various summer scholarship and contract activities across ARL. The goal of the program is to recognize and publicize exceptional achievements made by the students and their mentors in the support of Army science.

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Analysis of Impulse Data from Combined Blast/Fragment Experiments and Application to Rigid-body Modeling

Abell, Danielle

Under-body blasts are one of the leading causes of casualties in current operations, but our capability to accurately and efficiently assess their effect on personnel and vehicles is limited. In order to achieve a better understanding of under-body blast effects, a series of tests were conducted to quantify the impulse imparted to a pendulum for cased and uncased explosives in free air and buried in soil. The impulse of the fragments from the cased shots was also independently calculated. Using these calculations, the effects of casing and burying the explosive were measured. Current loading models also have limited capabilities to accurately quantify the effects from a combined blast/fragment event. Loading models are required to develop input to under-body blast codes, such as the TRUCK rigid-body vehicle code. Traditionally, the TRUCK code has been used to estimate vehicle rigid-body motion, but it also has the capability to model a typical vehicle seat. A preliminary evaluation of this capability was started to achieve a better understanding of the response of the seat to an under-body blast.

U.S. Army Research Laboratory Power Line Unmanned Aerial Vehicle (UAV) Modeling and Simulation (ARLPLUMS)

Adelman, Ross

ARLPLUMS is a powerful, interactive graphical user interface (GUI) for calculating and visualizing the **E**-Field and **H**-Field around power lines. ARLPLUMS allows the user to set the geometry of the lines and the load conditions on those lines, and then calculate E_y, E_z, H_y, or H_z along an unmanned aerial vehicle (UAV) path or cutting plane, or in the form of a movie. Even though it uses some simplifying assumptions about the geometry (i.e., the ground beneath the power lines is perfectly flat; power lines are perfectly straight, don't sag, and are parallel to the ground and each other; and no power poles or other conducting objects are near the lines), the results are excellent, providing a 90% solution in just a few minutes. Given the speed and adjustability of the program, users can experiment with different geometries, load conditions, and UAV paths to obtain a solid understanding of the underlying physics. Further, ARLPLUMS stores the voltage, current, **E**-Field, and **H**-Field on the lines as phasors (where they are determined by the root-mean-square [rms] value, phase, and frequency), which allows one to investigate what the fields look like due to each line separately and what kind of cancellations occur from all of them together. The only place where ARLPLUMS does not use phasors is when calculating the UAV signatures, which it does entirely in the time domain. After choosing the parameters, the user can then calculate and visualize the **E**-Field and **H**-Field by calculating time-domain signatures for the fields along a user-defined UAV path; calculating the fields along a cutting plane; and generating a movie showing the fields along a cutting plane over one complete AC cycle.

Implementation of an Analog Hardware-based Artificial Neural Network Framework with Memristors for use in Biomimetic Locomotion Control Systems

Albert, Stephen

In the future of reconnaissance and combat, small unmanned systems will prove invaluable. One of the primary focuses in small unmanned systems design is mesoscale ornithopter (flapping-wing) vehicles. The design of the hovering ornithopter has not yet been mastered, but almost every current design is an attempt to mimic biology as closely as possible under the current limits of actuator and materials technology. This *biomimetic* approach is a very useful, as it strives toward a design that has already been incredibly successful. In order to control systems of actuators such as these, small, low-power, and inexpensive hardware is required. Artificial neural networks, which have been shown to mimic complicated functions well, may prove ideal for the task. Specialized neural computation hardware exists, but it is primarily digital; any network that is modifiable requires memory, and current analog memory is complicated and difficult to manufacture. This paper proposes the addition of the memristor, a new circuit element whose resistance changes based on its charge, as a non-volatile memory element. Memristors are not yet in mass production, so the goal of this project is to simulate a functioning analog neural network that uses memristors to store its weights.

Erbium-doped Glass as a Potential Fiber Gain Medium

Asare, Nana

Rare earth doped glasses and crystals display relatively strong absorption bands, sharp fluorescent lines, and moderate to high quantum efficiency for the fluorescence transition of interest. Glasses have great optical qualities and can be drawn into fibers for fiber lasers. Erbium-doped glass is particularly important because its emission peak of 1.55 μm, arising from the transition between $^4I_{15/2}$ and $^4I_{13/2}$ manifold, is great for various military applications in which eye safety is a concern. Glasses (silicates) doped with different concentrations of erbium ions (0.1%, 0.7%, 1%, 3%) were studied as candidates for fiber amplifiers. Absorption spectroscopy was performed on the four samples at room and low temperature, and will be used to predict the emission cross-section spectra from measured fluorescence and vice versa through reciprocity. To obtain consistent measurements, the same settings and experimental setups were used for the absorption experiment. Fluorescence experiments are planned and will be treated likewise to reduce experimental errors.

Analysis of the Influence of Socio-cultural Factors on Usability of Mobile Applications

Bagley, Katherine

Mobile devices are ubiquitous in the fields of education, health care, entertainment, and, more recently, military applications. From a military perspective, the ultimate goal for these highly sophisticated devices is to assist Soldiers in achieving mission success across the evolving spectrums of operations, environments, and threats. Since mission success is often dependent on the interaction between the Soldier and the device, it is critical for designers to concentrate on understanding that unique interaction. An underlying factor in this understanding is enhancing the overall usability of the human-machine interface. Usability is defined as how ―user-friendly" a device is or how well the design of the device allows users to meet their intended goals, i.e., how intuitive and efficient it is to use. Factors that affect usability include task requirements, cognitive constraints, cultural biases, and the environment. Although numerous usability studies of mobile devices have been conducted, there has been little research exploring how socio-cultural factors influence usability.

The purpose of this research is to examine how socio-cultural factors affect the usability of mobile devices in a military environment. The results of this work will be used to create guidelines to assist in the development of tools that support Soldier/commander decision making.

Designing Bondable Metal Surfaces with Silane

Batykefer, Noelle

The summer research project involves designing optimally bondable surfaces. Historically, surface treatments have been developed for bonding metal surfaces that include metallic oxide treatments followed by organic primers that promote chemical adhesion between the surfaces. These technologies are available commercially through a variety of vendors. Among the leading components in adhesion promoters and primers are silane chemical groups that chemically bond to the metal oxide surface and subsequently have reactive end groups that react with the bonding adhesive. This chemistry creates a strong physical link between substrates and adhesives, and results in durable bonds. The goal of this project is to explore various silane functional groups and blends along with processing variables to understand the characteristics that most strongly affect bonding performance. Initial statistical studies are performed using (3-glycidoxypropyl) trimethoxysilane (γ-GPS) on 2024-T3 aluminum coupons with Cytec FM94K film adhesive to create a baseline set of properties that could be used to understand variability associated with statistical variables. Laboratory work requires fabrication of custom bonding jigs to create coupon standards according to ASTM D1002-2006 and formulation of silane blends to control bonding strength. Once a statistical set of coupons is completed, additional variables will be explored to evaluate bond performance.

I wish to acknowledge the mentorship of James Sands.

Bioinspired Superhydrophobic and Self-cleaning Surfaces

Beatty, Glenn M.

In nature, hierarchically assembled surfaces such as lotus leaves offer multiple functions, including photoabsorption, hydrophobicity, and self-cleaning. In order to engineer materials with similar functionalities, it is critically important to develop a fundamental understanding of the chemical and physical properties of the species considered. The goal of this study is to investigate the chemical composition, hierarchical structure, and physical properties of three different species of lotus, namely *Nelumbo nucifera*, *Nelumbo lutea*, and the Chinese bowl lotus, a cultivar of *N. nucifera.* The leaf surfaces of each plant are currently being analyzed using contact angle, contact angle hysteresis, and tilt-off angle. Environmental scanning electron microscope imaging will be used to analyze the complex surface structure of each species. The shape, size, and density of structures on the leaf surfaces will be compared at both the micro- and nano-scales. These images should provide a means of correlating the discrepancies in each species' surface structure to its particular hydrophobic performance. This study represents the first formal comparison of multiple lotus species on the basis of hydrophobicity and self-cleaning characteristics. The results and knowledge generated will allow for the future development of self-cleaning, superhydrophobic surfaces, possibly with additional functionalities.

Supplementing the Improved Performance Research Integration Tool (IMPRINT) with Cognitive Architectures

Best, Christopher

The Improved Performance Research Integration Tool (IMPRINT) can be used to model the cognitive workload experienced during interface operation. I investigated IMPRINT to examine its features, use cases, cognitive modeling paradigm, and faults with the goal of identifying opportunities to enhance its modeling power with cognitive architectures. I studied and compared the capabilities and design goals of two cognitive architectures, Adaptive Control of Thought-Rational – Queueing Networks (ACTR-QN) and Soar. I then identified the aspects of each that can be used to supplement IMPRINT. Based on this work, I propose several methods for adding or replacing IMPRINT features by making use of the cognitive architectures. I conclude that both ACTR-QN and Soar can be used to enhance IMPRINT's modeling capabilities and accuracy.

Spiking Neural Networks and Image Recognition

Blanda, Stephanie

The use of robotics allows the Army to increase its force while removing Soldiers from harm's way. Currently, the Army's use of robots is mostly limited to teleoperations and semi-autonomous systems. Our goal is to increase autonomy by applying a well-established cognitive psychological approach, namely, neural network modeling, to robotics. We train a neural network using Hebbian learning to identify different scenes viewed by a camera. The winner-take-all mechanism is implemented to promote competitive learning among the output neurons. We implement both supervised and unsupervised winner-take-all. To choose the winning neuron, supervised winner-take-all depends on the user supplying category/label information about the input; whereas, for unsupervised winner-take-all, the network chooses the winner based on the inter-spike time interval. In our implementation, each output neuron is restricted to learning only one category. We tested both algorithms on a set of two distinct images and found that the winner can be seen as the output neuron that was spiking most vigorously during the time interval that its learned image was presented. Though this paper focuses on the use of neural networks for image recognition, the algorithms developed have implications for more general intelligent systems.

I wish to acknowledge the mentorship of Troy Kelley.

Motion Simulation in the Environment for Auditory Research

Boren, Braxton

Virtual sound source motion has been implemented in the U.S. Army Research Laboratory's Environment for Auditory Research, which contains a 57-channel spherical loudspeaker array located in a semi-anechoic chamber. Using the low-latency PortAudio application programming interface from the Psychophysics Toolbox Version 3, we are able to dynamically update 57 channels of streaming audio in real time using MATLAB for signal processing. Both Distance-Based Amplitude Panning (DBAP) and Vector-Base Amplitude Panning (VBAP) have been implemented in MATLAB for controlling source motion. Sources are defined on a given path, such as a circle, ellipse, or the "dog bone" pattern often used in aviation. Although DBAP works convincingly for virtual sources located on the sphere defined by the loudspeaker array, VBAP is needed to position sources outside the array. Source motion paths are defined parametrically with respect to time, and the playback buffer updates the panned position every 11.5 ms. Based on the source's instantaneous distance, diffuse-field or free-field amplitude attenuation is added in MATLAB, as is air absorption filtering. This virtual sound source method will be used for a variety of audio simulations and auditory experiments.

Synthesis and Characterization of Bio-based Unsaturated Polyester Resins for Use in Composite Applications

Buchanan, Rachel

Recently, the Department of Defense (DoD) has come to rely on composite materials in a growing number of platforms due to their improved characteristics when compared to traditional building materials. Most commercial resins and composites are petroleum based, which is a concern due to the fluctuating price of crude oil. To this end, the development of bio-based (bioUPE) resins as drop-in replacements for petroleum-derived resins is gaining increased interest. First-generation bioUPE systems based on one pot synthesis have suffered from poor thermal and mechanical properties. Thus, this work examines a two-step synthesis procedure to produce satisfactory materials. In the first step, maleate groups are attached directly to the isosorbide core structure to provide rigidity. Secondly, the novel diester is linked together into unsaturated polyesters using a secondary diol to improve the solubility in reactive diluents. Initial results show that using the catalyst p-toluenesulfonic acid for both steps yields the best results and the progress of the reaction can be monitored by acid number titrations. The resins will be cured with methyl methacrylate or styrene to form a hard solid. The glass transition temperature and modulus as a function of temperature will be measured to assess whether the two-step synthetic scheme improves the rigidity of the resulting polymer.

I wish to acknowledge the mentorship of Josh Sadler.

Grain Orientation Effects on Single Crystal Properties of Aluminum Oxynitride (AlON)

Cadel, Daniel R.

Nanoindentation is an efficient experimental methodology for obtaining modulus, hardness, and fracture toughness of a wide range of materials. In order to obtain these three values from a single test run, certain indenter tips, such as the pyramidal Berkovich tip, are optimal. However, this geometry forces cracks to initiate and propagate along predefined paths, independent of grain orientation. In contrast, use of a spherical indenter tip allows for cracks to develop based on inherent properties of the grains. Combining indentation testing with imaging by electron backscatter diffraction (EBSD) allows for a comparison of crack direction with grain orientation. By using a MATLAB® program to obtain crack length and direction in the sample reference frame, Euler angles from EBSD can be used to transform the cracks into the grain reference frame. Thus, cleavage planes can be identified and statistically analyzed within single grains, and checked among multiple grains for each type of material used. This method will be applied to fused silica, as well as the transparent armor ceramic aluminum oxynitride (AlON). The results can be applied in the formation of a theoretical model for AlON material response.

Dual-unilateral Master-slave Controllers for Robust Control of Dexterous Manipulators

Cannon, Daniel

Dexterous robotic manipulators that rely on joystick-type interfaces for tele-operation require considerable time and effort to master and lack an intuitive basis for human-robot interaction. These factors can hamper operator performance, increase cognitive workload, and limit overall user effectiveness on highly dexterous tasks. Master-slave interfaces (MSIs) used in such fields as animatronics, tele-surgery, and remote-handling of hazardous materials are intuitive, and have proven effective in improving operator performance on these manipulators. However, MSIs are usually limited in their operation because they typically offer only unilateral control for anthropomorphic manipulators and operate without force-feedback on these interfaces. When force-feedback is used, it can lead to instabilities in MS controllers due to the need to bilaterally send and receive signals with the remote manipulator. Bilateral communication in control systems is prone to accumulating errors, leading to instability. We can mitigate the effects of the instability and reduce errors in these systems by separating the bilateral communication into dual-unilateral (DU) communication. The research methodology concentrates on analyzing a DU control scheme with the focus on ways to reduce or eliminate MSI issues such as latency, error, and information loss, while providing the user with accurate force-feedback capability and transparency during operation.

Synthesis and Transfer of Pristine Graphene for Transparent Electrode Application
Choi, Daniel

Synthesis of graphene and other carbon based nanomaterials require a great amount of energy, control, and time to achieve. If one of these components is not in accordance with the others, defects such as functionaliztion, flaws in geometry, and possible deformation of graphene could be present. To prevent these flaws from materializing, different methods have been attempted to produce pristine graphene that could be used in practical applications. In this paper, chemical vapor deposition (CVD) methodologies, coupled with optimization of various synthesis parameters such as gas flow, temperature, and pressure control, was used to produce single- to few-layer graphene films on a copper metal substrates. After synthesis, the graphene films were transferred to desired substrates, including silicon (Si)/silicon dioxide (SiO_2) and fluorine tin oxide (FTO) for more practical applications. Additionally, characterization of the graphene film was performed using Raman spectroscopy and two different microcopies to measure the effectiveness of the synthesis method in terms of number of layers produced, presence of defects, and overall quality of the graphene film. It was determined that after CVD and chemical etching, the characterizations showed that overall quality of graphene is adequate for use in practical applications such as optically transparent solar cells electrodes.

The Effect of Copper Etchants on the Structural Properties of Transferred Graphene

Chu, Albert

The effect of copper etchants on the structural properties of transferred graphene will be investigated in this work. Graphene has been successfully grown on copper foil substrates and transferred to silicon dioxide (SiO_2)/silicon (Si) substrates. However, the process of isolating and transferring graphene from the substrate is delicate, as multiple processes are involved that can influence its structural and chemical properties. In the transfer process, the graphene is coated with a protective poly(methyl methacrylate) layer, and the substrate metal is wet chemical etched away. Particular copper etchants have been shown to leave residue and/or alter the chemical or structural properties of graphene, which can be detected as peak position shifts in the characteristic Raman signature. Three copper etchants solutions, based on ferric chloride, ammonium persulfate, and iron nitrate, respectively, will be compared. Once transferred, the graphene will be characterized by Raman spectroscopy measurements and atomic force microscopy (AFM). The Raman scans will reveal data concerning the graphene structure, and the AFM will show any residual chemicals above or below the graphene surface. Coupled together, the AFM and Raman data will provide a better understanding of the mechanisms affecting the graphene structure.

Aging Studies of Discharged Lithium Poly-carbon Monofluoride (LiCF$_X$) Cathodes

Collins, Evan

Lithium poly-carbon monofluoride (Li/CF$_X$) cells have the potential for use in communication applications requiring a high specific energy primary power source is required. Li/CF$_X$ cells have been used primarily in low rate applications. At higher rates, Li/CF$_X$ cells generate a significant amount of thermal power and mechanical deformations of the cell caused by cathode swelling. Our previous work has shown that amorphous lithium fluoride (LiF) forms on the internal surfaces of the discharged carbon shells and that the thermal power present after discharge is a result of the Ostwald ripening of this amorphous LiF. In order to address these shortcomings of an otherwise promising material, the underlying mechanisms of LiF formation and swelling must be more thoroughly understood. In this paper, we investigate the relationship between LiF crystal growth and cathode swelling post-discharge by measuring the cathode swelling at different aging temperatures as a function of time. Aged cathodes were also characterized by x-ray diffraction and scanning electron microscopy.

Infantry Fighting Vehicle (IFV) Driver Animation

Collins, Ryan

The Improved Performance Research Integration Tool (IMPRINT) simulation was limited in what it could display during a model run. For example, the IMPRINT model of the Bradley consisted of boxes with task names representing driving. With the new animation feature in IMPRINT, I was able to create a visual representation of the interfaces for the driver of an M2A3 Bradley Infantry Fighting Vehicle (IFV). This representation allowed viewers of the Bradley driver model to see what the driver would be doing during a model run. Thus, the focus of my project was to enhance understanding of Bradley drivers' tasks through the animation. Because it is now possible to see what the drivers are doing, project managers are more likely to make changes that improve the vehicle design, hence benefitting Soldiers and increasing mission success.

Sonochemical Synthesis of Gold-Silver (Au-Ag) Core-shell Nanoparticles

Dandekar, Vinay

Gold-Silver (Au-Ag) core-shell nanoparticles are investigated for their possible applications in solar cells, biology, transistors, and light-emitting diodes (LEDs). The core-shell structure can be useful for creating new particles that have the properties of both the core material and the shell material. The Au-Ag nanoparticles were characterized electrically, optically, and structurally by using a scanning tunneling microscope (STM), ultraviolet-visible (UV-Vis) spectroscopy, and an atomic field microscope (AFM), respectively. A novel sonochemical approach was used with varying parameters to determine the optimal synthesis parameters for precise control of particle size, geometry, and electrical properties. It was determined that a longer duration of sonication decreases the particle size of the Au-Ag nanoparticles and that the core-shell particles exhibited absorption wavelengths similar to Au nanoparticles, suggesting that Au composes the core of the nanoparticle. The core-shell quantum dots (QDs) were applied as a sensitizer in dye sensitized solar cells for energy harvesting applications.

Numerical Investigations of Methods of Spinal Injuries

Desai, Vivek

Many injuries occur due to improvised explosive devices (IEDs). High stress and loading rates from vehicles driving over IEDs may cause spinal injuries. In this project, various computational modeling techniques are explored such as peridynamics and finite element modeling to model the spine. Through collaboration with Dr. Anton Dmitriev, the Director of the Spine Research Center at Walter Reed Army Military Medical Center, the geometry for the spine model is obtained. The geometry and meshes for the peridynamic and finite element meshing portion of the project is done in CUBIT, a finite element modeling mesh program developed by Sandia National Laboratory. After simple tension and compression, problems are computed on an Army supercomputer using parallel processing.

Building Detection and Contour Approximation from Aerial Light Detection and Ranging (LiDAR) Data

Doria, David

Locating and modeling buildings in aerial light detection and ranging (LiDAR) data are of critical importance to the Army. This type of information plays a vital role in many military applications, including mission planning, ballistic threat assessment, radio communication network modeling, and weather modeling. Due to the nature of the acquisition process, vertical surfaces are not seen directly by the LiDAR sensor but are nonetheless a very important part of the data. In this paper, we present a process to locate and model buildings and their vertical surfaces. Our system is completely automatic and requires no user intervention. We present results on real data that show that this process detects and accurately models the same buildings that a human would pick out of the data.

Optimization of Allele-specific Polymerase Chain Reaction (PCR) for Detection of Single Nucleotide Polymorphisms (SNPs) within *Bacillus Globigii*

Dupuis, Christopher

Single mutations, or single nucleotide polymorphisms (SNPs), in the bacterial genome can render organisms more virulent or drug resistant. For this reason, whole genome sequencing is used in forensic genetics to identify SNPs in bacteria. It is important to determine whether virulent phenotypes arising from SNPs are naturally occurring or selected by humans. This study focuses on designing allele-specific polymerase chain reaction (PCR) assay for the detection of the hypersporulating species in a mixed culture of hyper- and hypo- sporulating bacteria. For our work, we chose the hyposporulating strain Detrick 1 and the hypersporulating strain Detrick 2 from the Army anthrax model, *Bacillus globigii*. We considered primers made of natural nucleotides and primers with locked nucleic acids at the mutation site. The results show that the primers with locked nucleic acids allowed for better discrimination over a wider temperature range than the natural primers.

Magnetic Barkhausen Noise Assessment of Welded Armor

Fudger, Sean J

The U.S. Army Research Laboratory is currently evaluating a non-destructive method for characterizing residual stresses in welded armor. Magnetic Barkhausen noise (MBN) is the technique under assessment. Microscopically, ferromagnetic materials are divided into domains or regions of uniform magnetic polarization. The application of a magnetic field causes the orientation of these domains and their boundaries to shift. Discontinuous steps exist between these boundaries caused by changes in flux density, which have been termed ―Barkhausen jumps." Barkhausen noise is the term used for the sum of all the signals that result from these ―jumps." Previous findings have shown Barkhausen noise to be a useful tool in detecting grain boundaries, voids, surface cracking, and specifically, residual stresses. MBN is being used as a qualitative comparison to x-ray diffraction (XRD) residual stress results from measurements performed at various locations on the welded armor.

Interface Design Using NASA World Wind Java

Gallardo, Esthela

World Wind is a three-dimensional geospatial visualization developed by the National Aeronautics and Space Administration. The project is open source and available on all platforms. World Wind is ideal for scientific use due to its portability, software architecture, and the vast amount of information it provides. For this project, World Wind was used as a component on a user interface for a graphical processing unit (GPU) accelerated code. The GPU accelerated code performs an optimization that, given information about a specified area, advises a Soldier on the best way to mobilize. The optimization attempts to reduce the risk of encountering any danger and increases military observation over the specified area. Familiarization with the World Wind API facilitated the development of a user interface, as it contained a sample application that could be easily manipulated to fit the requirements of the optimization. The user interface is not yet complete. Several aspects of the interface have been addressed, but it has not been integrated with the GPU accelerated code. Therefore, this paper focuses on the design and development of the user interface.

Effect of Catalyst Acidity on Isobutanol Conversion

Gamson, Adam

This study focused on the effect of acidic support material. Alumina was the first support material tested, followed by zeolite and silica powder. Zeolite is composed of alumina and silica oxides. An increase in the Si/Al ratio leads to an increase in acidity, which is why CBV780 and CBV720 with ratios of 80 and 30 were selected. Each catalyst configuration was tested at three residence times: 25, 56, and 128 ms. Φ's tested ranged from 0.1757 to 6.3377. The product gas composition was monitored throughout testing, and BET surface area characterization of each surface coating material was performed.

Our findings suggest that overall conversion of isobutanol was increased with alumina support compared to silica at short residence times and in the presence of more acidic zeolite. Moreover, the hydrogen selectivity shows that Rh and more acidic support coats increased the hydrogen production for all catalysts. Our data show that alumina had higher olefin selectivity than silica, and that high acidity decreased olefin production; additionally, Rh decreased olefin selectivity for all catalysts.

I wish to acknowledge the mentorship of Ivan Lee.

Platform for Testing and Quantifying Slow-computing Based Control Technique

Ganesan, Vishnu

Stringent size, weight, and power requirements of micro-autonomous vehicles make it difficult to scale down traditional robotic control paradigms. Novel architectures that can operate under these constraints are needed. Bio-plausible ―slow computing" algorithms developed by the Murray Group at Caltech provide one such approach. These algorithms are fundamentally based on processing computations across massively parallel, asynchronous systems, similar to those found in nature. Bio-plausible control laws have already been developed for purposes such as stabilization; however, research has not been done to quantify and compare the slow-computing approach with traditional control theory. We will develop a testing platform that can be used to generate data needed to quantitatively compare the two approaches. We will determine whether the bio-plausible control algorithms previously developed for attitude stabilization in an aerial platform can be modified to work on a one-dimensional (1-D) rotating model, and implement our control in a single dimension for simplicity. We will design a controllable gimbaled platform with a linear array of optical sensors, and will identify an appropriate challenge (e.g., stabilization, localization) as the test by which to measure the algorithm performance (e.g., error, speed, power, flops).

Improving Military Standard 1472 for Assessments of Physical Accommodation

Garneau, Christopher

The assessments of the users' physical accommodation examine the interaction between the spatial configuration of a product or environment and the size of the humans that use the product. Such assessments address many questions. For instance, what groups of people will use the product? Will these intended users experience comfortable and safe interaction with the product? Does the product meet regulatory guidelines? Is the product cost-effective? Is the product robust to changes in the intended user population(s)? For the U.S. military, military standard 1472 is a key tool for specifying contractor requirements, testing and evaluating existing equipment, and proposing design revisions related to users' physical accommodation. First published in 1968 and currently in its sixth revision (version F), the subsection of the standard related to physical accommodation has limitations—for instance, it includes outmoded univariate body dimension data. This paper investigates how to enhance the standard by capitalizing on benefits of interactive mobile technology to make it a better analysis tool. In particular, design specification or testing and evaluation usage scenarios are investigated. A mobile software tool is proposed that considers these contexts and aids in properly applying statistical principles for analyzing physical accommodation.

Environmentally Friendly Thinners for Military Coating Systems

Gettelman, Jacob

Currently, the only approved thinner blends used in military coating systems have a high level of volatile organic compounds (VOCs) and volatile organic hazardous air pollutants (VOHAPs). In an effort to improve on the VOC/VOHAP content in approved thinners, newer and more environmentally friendly thinners have been developed that are designed to eliminate VOHAPs and significantly lower VOCs. These new thinners must also be able to work the same, if not better, than current thinners in the field and in any other applications in which the current thinners are being used, specifically, when being used with solvent-borne polyurethanes and solvent-borne epoxies. The areas in which these new thinners need to perform are thinning, flushing, and cleaning. Additionally, they cannot affect the cure time or pot life of the coatings once the thinners are added in nor can they exhibit a decrease in corrosion or weathering performance. These new thinners have already been tested and found to perform adequately with Army topcoats and primers and are now being tested for use in Navy topcoats and primers.

Digital Image Correlation of Flapping Wings for Micro-technologies

Hall, Leslie

The unpredictable and inherently dangerous situations Soldiers' experience have created a demand for advanced environmental knowledge of impending threats. Small, stealthy, and versatile micro-technologies have great potential in this area and can provide autonomous reconnaissance and non-lethal protection while either crawling or flying. One particular challenge with flying systems is designing a lightweight vehicle while maintaining critical function performance. This project focuses on using digital image correlation software and high-speed cameras to analyze lightweight flapping wings for micro-systems use. To understand the parametric design space, a design of experiments is created, varying wing span, chord, shape, and spar count. Then the wings are manufactured using a three-dimensional printer and thin plastic sheeting. A custom-made load cell measures the thrust and lift of the speckled wings, which are mounted on and powered by a bimorph actuator. The stereo setup assesses the wing's speckle pattern and measures the change in light intensity, which correlates to wing structure movement or deformation. This enables the calculation of important wing parameter trends, including strain, position, velocity, and acceleration. Computational modeling verifies these results while identifying design features that enhance flight performance and support a lightweight and efficient micro-system design.

Multilayer Thin Film Capacitor by ALD and Selective Etching Techniques

Hamm, Steven

A process will be developed for the fabrication of thin film multilayer capacitors using an atomic layer deposition (ALD) tool and selective wet etching methods. This process will be used to create capacitor devices that occupy <1 cm^2, obtain a capacitance of 10 uF, and withstand voltages >12 V. Platinum (Pt) and ruthenium (Ru) metals will be used as electrode materials because of the high selectivity of aqua regia and ceric ammonium nitrate etching solutions, respectively. Various dielectric materials, including aluminum oxide (Al$_2$O$_3$) and hafnium oxide (HfO$_2$), will be investigated and selected for final device fabrication based on performance and the minimal amount of layers needed to reach the desired properties. The electrical characteristics for an assortment of layers will be investigated.

Growth and Transfer of Graphene for Device Fabrication

Hauri, Kevin

The unique electronic properties of graphene enable the development of field effect transistors with potential for speeds much higher than the existing technology. Diluted methane chemical vapor deposition growth of graphene on a nickel substrate has resulted in potentially useful multilayer graphene layers. These graphene layers were grown on nickel substrates deposited onto silicon (Si)/silicon dioxide (SiO_2) wafers by evaporation and sputter methods. The graphene must be transferred from the nickel substrate onto a template more suitable for device fabrication. However, the current graphene transfer process is not fully mature and presents a number of challenges. In the transfer process, a polymer coating is applied to the graphene, and the original materials underneath are removed. A coating of photoresist is spun and hardened on top of the graphene, and then the substrate is removed with a buffered oxide etch and a nickel etch. One challenge is removal of the photoresist from the surface of the graphene without film wrinkles, cracks, and contamination. Alternative solutions that minimize damage to the graphene during the transfer process are currently being explored.

Synthesis and Characterization of Metallo-supramolecular Polyurethanes

Havlik, Alexandra L.; Lambeth, Robert H.

The synthesis and characterization of a bio-inspired metallo-supramolecular polymer is reported. A polyurethane copolymer with metal-ligand domains integrated into the polymer backbone was synthesized in an effort to enhance the mechanical properties of the polymer. The ligand 2,6-bis(1-ethyl-5-hydroxybenzimidazol-2-yl)pyridine was synthesized in a five-step reaction sequence, starting from chelidamic acid and 3-chloro-4-nitroaniline. The ligand was incorporated as a chain extender into a polyurethane polymer backbone. The binding properties of the ligand functionalized polymer will be characterized by ultraviolet/visible (UV/Vis) and capillary viscometry.

Generating Random Graphs with Small World Properties

Herzog, Alexander

Generating graphs with various properties, such as the small-world property, is difficult by hand, especially for networks with a large number of vertices and a desired graph property that requires visiting each vertex to determine that property. This paper presents an algorithm, the Cluster Specific Graph Algorithm (CSGA), for generating a random, simple, undirected, and unweighted graph that exhibits a desired clustering coefficient given a number of nodes and a range of node degrees. The algorithm is broken into three phases: random degree–sequence generation, graph connection and randomization, and clustering coefficient adjustment. Each phase incorporates checks to ensure the algorithm does not advance if desired conditions are not satisfied or to terminate the program if it is believed the graph cannot be created. This paper also describes the graph theorems that were necessary for CSGA. CSGA works well at different node sizes but is more accurate for graphs with a large number of nodes since a small number of nodes presents less opportunity for alteration. CSGA is simple and easy to implement but leaves plenty of room for optimization and greater efficiency.

Constraint-Based Hybrid Cellular Automaton Topology Optimization for Advanced Lightweight Blast Resistant Structure Development

Hofstetter, Jr. Dwight D.

Improvised explosive devices (IEDs) are a continually changing threat to vehicles on the modern battlefield. Re-engineering is needed to keep up with these changing threats and to safeguard the vehicles and Soldiers. The most direct form of re-engineering is the development of "add-on" protection kits. These kits are a concession between maximum strength and minimum weight. Livermore Software Topology and Shape Computations (LS-TaSC) optimization software is a constraint-based hybrid cellular automaton tool that can be used to design the optimum solution. This software takes into account size, shape, topology, and topometry (changing of element properties on an element-by-element basis). The optimization is achieved by designing for a uniform internal energy density, while constraining components such as plastic strains and von Mises stresses. This paper explores the LS-TaSC optimization software, with regards to its usefulness to the U.S. Army Research Laboratory (ARL) engineers in the field of vehicle protection technology development, with the ultimate goal of enhancing Soldier survivability.

Determining Network Topology From Component Failure Observations

Holbert, Brett

The ability to identify failures in network components can be complicated when the full topology of the network is not known. In addition to hiding the true cause of some failures, the unknown areas of the network can obscure which links are most important when repairing the faults. This paper presents a network inference algorithm to complement the netCSI algorithm for fault diagnosis. The new algorithm uses sets of simultaneous failures identified by netCSI to combine links that cannot be detected by traceroute or other network discovery tools. By determining which links failed at the same time, we are able to prevent some pairs of links from being merged together while others appear to be more similar. Although the algorithm has not yet been tested, the testing process has been designed, and possible modifications are already planned in case alterations are necessary.

Implementation of Database Archiving for Composite Materials Mechanical Analysis

Hollifield, James

A centralized database to capture research generated composite material data will allow the Army to correlate coupon-level material performance to real-world performance, preserve data, ensure data integrity, and streamline the use and distribution of material information. Through the use of Materials Selection Analysis Tool (MSAT) in Material and Processing Technology Information System (MAPTIS), the Army will be able to efficiently screen and characterize a wide variety of materials through standardized test methods. A tool of this nature is of high value due to the Army's broad-based material selection needs and for optimizing material performance for Army applications. Currently, the Army is in ―beta‖ stage development of the database, which consists of two core components. One component is the development of a specific tensile test method that ensures uniformity of the data output files for importing into the MAPTIS database. The other component is implementation of this method to establish successful equipment integration for the transition of data into MAPTIS. Experimental laminates have been fabricated using the vacuum-assisted resin transfer molding (VARTM) process and are being evaluated in various test methods to create the test parameters for the MSAT database optimizer.

Continued Development of the Automobile Radio Adaptor

Hopkins, Robert

The Automotive Radio Adaptor (ARA) system provides a radio with radio frequency amplification, battery backup, power conditioning, and rapid radio removal capabilities. These capabilities are presented in a modular system with a power box and radio boxes. The original prototype system only provided one type of radio box designed to interface with a Multiband Inter/Intra Team Radio (MBITR), but the idea of having a modular system is to provide all the mentioned capabilities to a Harris PRC-152 as well as an MBITR. The two radios ultimately required different radio boxes because of different radio latch designs, improvements in assembly, and an added power supply for charging the Harris 152 radio. The Harris radio box also benefited from a more serviceable box design. The added radio box adds versatility and usability to the ARA system.

Construction of Transposon Mutant Library of *Clostridium acetobutylicum*

Jacob, Christina

A microbial fuel cell (MFC) is a bio-electrochemical device that makes use of bacteria to create electricity. Traditionally, these MFCs require a mediator to help transfer electrons to the electrode, allowing the fuel cell to be electrochemically active. Recently, however, it has been discovered that a mediator-less MFC is possible with the use of electrogenic bacteria, which help transfer electrons from the bacterial environment to an electrode. One such electrogenic organism is *Clostridium acetobutylicum*, which has been used extensively at the U.S. Army Research Laboratory (ARL) and has been determined to be of interest in the MFC community. Through the testing of different colored-dyes and their de-colorization (through reduction of the dye) by *C. acetobutylicum*, it is possible to visually verify its reducing abilities. In addition to testing decolorization, a *C. acetobutylicum* clone library will be created using a transposon. This transposon randomly inserts its DNA into the bacterial DNA, thereby creating a library. This library will be screened against decolorization of dyes in order to determine the genes necessary for this organism to be electrochemically active in an MFC. The creation of this library will provide a powerful tool for future screening experiments with this model organism.

Requirements Analysis of a Notional Joint Multirole Rotorcraft using Interval Methods

Johnson, Kevin Lee

The lack of requirements analysis tools in the early stages of design is the source of many deficiencies, which can result in late deliverables and budget overruns. This work focuses on developing a method that determines bounds on input variables resulting from limits on performance requirements; the end result being an understanding of the feasible design space. This technique, which uses interval mathematics, is applied to the requirements definition of a notional Joint Multirole Rotorcraft, for example, determining payload and range combinations that produce a vehicle of a desired gross weight. For clarity, I provide a brief overview of a few two-dimensional trade studies, including Langermann, combination sine and cosine, and Rastrigin functions. The number of function calls is compared to the filtered Monte Carlo method, a standard method in design space and requirements exploration. It is expected that for many types of problems, interval methods will require fewer function calls than other global search methods such as filtered Monte Carlo and genetic algorithms. The interval method guarantees finding all the solutions to a rational function and allows the tolerance on the solution boxes to be specified. The conclusion of the analysis provides a framework for conducting benefit and cost trade studies on requirements of a future joint multirole rotorcraft.

Iris Recognition Using Sparse Representation and Hamming Distance

Jones, Michael

Many algorithms exist that can perform iris recognition. Because there are multiple approaches, impartial testing methods must be used to compare the algorithms. To develop a framework to fairly compare iris algorithms, we implemented and tested two iris recognition algorithms. The first algorithm, developed by Masek et al., employed techniques similar to the first iris recognition algorithm created by Daugman. The second algorithm, developed by Pillai et al., used techniques based on sparse representations. Three experiments were conducted to compare the performance of the two algorithms and determine the receiver operating characteristics. To test the limits of the algorithms, we incorporated poorly acquired iris images suffering from segmentation errors, blur, and occlusion. After all the tests were performed, the results showed that the algorithm developed by Masek et al. performed better than the algorithm developed by Pillai et al.

EEG Filter Design for Near-Real-Time Signal Processing

Jordan, Kesshi

Electroencephalography (EEG) is a noninvasive low-cost method to study brain activity. The system consists of a headset with several electrodes that measure voltages produced by thousands of neurons in the brain firing in synchrony. The low signal-to-noise ratio of EEG data precludes the use of the system outside of an extremely controlled laboratory environment. Inconsistencies in data due to inter- and intra-personal variation present additional challenges to the field use of EEG. A filter that allows for real-time, frequency-specific analysis is a critical path to transition EEG technology from the laboratory to the field, enabling the practical study of Soldier cognitive function on a single-trial basis. MATLAB testing of filtering methods, including simple and multistage band-pass filters and several transforms (Fourier, Hilbert, and Wavelet), will be used with both simulated and experimental data to resolve an optimal filter design. A MATLAB-based software product with a graphical user interface and the capability to interface with EEGLAB processing software will be developed. This software realization will precede the ultimate goal of hardware implementation for a field-applicable system.

Microstructural Investigation and Evaluation of Mechanical Properties in Friction Stir Welded Joints

Justusson, Brian

With involvement of the United States Military in various places in the world, increased improvements in personnel and vehicle protection are needed. Traditionally, armoring techniques have performed well against particular threats; however, a new threat has emerged from improvised explosive devices (IEDs), which has exposed the vulnerability of the undercarriage of the vehicle to explosions. Various solutions have been proposed to combat this problem, such as implementation of a unibody construction of the chassis. While traditional joining techniques have shown promise, the variability in mechanical properties of the weldment can be costly and needs to be addressed. Friction Stir Welding (FSW) is a solid-state welding technique, which involves local softening of the material subjected to severe plastic deformation, coupled with a localized heat flux, creates a unique microstructure in and around the weld that is dependent on the FSW parameters. The current work involves the characterization of the microstructures that develop during FSW as it relates to the locally spatial mechanical properties in the weld zone. The microstructure will be characterized by using scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD) techniques, which, when coupled with mechanical testing data, can be used to shed light on the spatial stress-strain behavior of the welded sample.

Stimulated Brillouin Scattering (SBS) Suppression via Chirped Diode Lasers

Kacik, Natalie

High-power fiber lasers are a promising technology for the U.S. Army; however, stimulated Brillouin scattering (SBS) is currently limiting the power output of large mode area (LMA) fiber amplifiers (FAs). The goal of our research is to analyze the use of a chirped laser to decrease the SBS gain in a fiber. We calculated the SBS gain in chirped ytterbium (Yb) and erbium (Er) FAs as a function of chirp, fiber length, SBS bandwidth, and Stokes frequency. Current fiber lasers provide SBS gain throughout the entire length of the final stage amplifier. We are proposing to diminish the gain length by adding a chirp to the pump beam.

Investigations to Identify Candidate Adhesives for Ground Vehicle Armor Applications

Kaufman, Jonathan

The Army has unique adhesion needs, namely, strength and damage tolerance at high loading rates. The purpose of this project is to develop a rapid screening protocol to identify composite integral armor adhesive candidates. This screening protocol will be converted to a military performance specification, ―Minimal Adhesive Requirements for Ground Vehicle Applications." Materials informatics is being used to capture, organize, and explore the adhesive performance in a robust database. This paper addresses the challenges of standardizing and automating the data generation for quasi-static as well as supplemental dynamic tests. Variance in processing and testing of the adhesives are discussed. Due to the nature of the nonlinear adhesive response, common load-displacement analysis schemas are not optimal. This paper discusses the impact of such implications on the analysis of the complex adhesive response curve.

Parallel Stochastic Simulation of Bio-plausible Control

Koppel, Alec

During this study, we designed a simulation algorithm to compare bioplausible control with traditional control on a ―slow-computing" (i.e., massively parallel, asynchronously functioning) architecture. Bio-plausibility refers to a loose framework of engineering principles that seek to modify traditional control laws to reduce mathematical operations to primarily linear formulas that can be quickly executed in biological processes, especially on slow-computing systems. Stochastic simulation techniques from chemical kinetics will be adapted to this control context. To simulate a parallel computation structure on a single machine, time will be discretized and parallelized. We will assume the parallel computations will follow a Poisson process (or some approximation of the Poisson process) and discern appropriate rate functions to incorporate stochastic delay of computations. Appropriate weighting of the control matrix elements will be determined for a test bed experiment that will be designed in another part of the project to quantify the feasibility of the slow-computing approach. Through simulations, we will explore the numerical differences between bioplausible and traditional control on this slow-computing architecture and lay the groundwork for future experimental validation efforts.

Gel Polymer Electrolytes in Dye Sensitized Solar Cells

Koripella, Pradeep C.

The technologies implemented on the Future Force Soldier will primarily be powered by electrical energy, requiring an abundance of on-demand power sources. To reduce the need for cumbersome battery-based energy sources, solar energy harvesting has gained much attention. One of the most promising methods of solar harvesting for robust-field applications is through the use of dye-sensitized solar cells (DSSCs). The goal of this work is to increase the efficiency, flexibility, robustness, and life cycle of the DSSCs through the integration of micro-porous gel polymer electrolytes (GPEs) in place of traditional liquid electrolytes. Gel polymer electrolytes are non-volatile, chemically stable, and will reduce electrolyte leakages. Two different micro-porous GPEs were studied with varying micro-porous structure, and the impact of these structures on the DSSC efficiency was measured. GPEs composed of varying molarities using two different methodologies were pursued, focusing on polyvinylidene fluoride-co-hexafluoropropene (PVdF-HFP) in polyethylene glycol (PEG)/polyethylene glycol dimethacrylate (PEGDMA) solvents or a simple water plasticizer. For the first time, these GPEs were made with different polymer ratios and tested with TiO_2 nanotubes, rather than TiO_2 nanoparticles, in order to reduce electron recombination in the cell and increase DSSC efficiency.

Field Programmable Gate Arrays: Applications in Robotics

Kott, Gedalia

As autonomous technologies advance, the algorithms for robotic behaviors are becoming more complex and require more processing power. Also, autonomous technologies require more power-demanding sensors, which reduce the power available for processing. Small-scale autonomous robots have limited processing power due to their size. The hardware solutions currently available to increase processing power do not fully satisfy the requirements of small-scale robotics and can be improved upon.

The Asset Control and Behaviors Branch identified a hardware component that can improve their robotic hardware system using field-programmable gate arrays (FPGAs). FPGAs have been available for many years and have already been implemented in other robotic systems. In this paper, the benefits of using an FPGA are outlined and discussed with specific attention given to the needs of the Soldier and robot in military scenarios. We then present a review of the literature on FPGAs used in robotics. We conclude by making recommendations for implementing FPGAs in robotic hardware systems and discussing factors that can contribute to a better performing FPGA-based system.

Investigation of Integrating 3-D Geometry into the Visual Anatomical Injury Descriptor (Visual AID) Using WebGL

Kulaga, Autumn R.

The Visual Anatomical Injury Descriptor (Visual AID) is a graphical computer tool developed to illustrate injury and severity on an anatomical figure, allowing for communication of trauma. Currently, the tool uses two-dimensional images, rendered from three-dimensional (3-D) geometry, to convey injury. While integrating 3-D geometry was a part of the initial development plan, this step was delayed while waiting for technologies to mature. This paper discusses the Web-based 3-D environment prototype being developed to understand the feasibility of integrating WebGL into Visual AID. Using WebGL will permit us to display the current anatomical geometry used by Visual AID in a 3-D Web-based environment. Employing a 3-D environment allows us to more accurately display the geometry, thus providing a better navigation system and the potential to add annotations fixed to 3-D points. Further developments must be made to better understand integration of highly detailed geometry as well as changing geometry attributes at runtime, such as Abbreviated Injury Scale (AIS) code, severity, and color association. WebGL is a novel cross-platform technology that must be further explored as standardization occurs, thus enabling future advancements. The already explored features will enhance Visual AID's injury illustrating capabilities, facilitating the communication of injury data.

Development of a Method for Sputtering ZrCuAlNi Amorphous Metal

Landau, Nick

One of the challenges in constructing metal-insulator-metal (MIM) diodes has always been obtaining a sufficiently smooth, uniform surface at the metal-insulator surfaces. Most metals have crystalline structures that, when deposited, can contribute to surface roughnesses greater than MIM insulator thicknesses (typically, ~5 nm). Poor smoothness at the material interfaces compromises the device's functionality by creating non-uniform electron tunneling barriers that lead to erratic device performance and low yield. The adaptation of a sputtering process for amorphous metal zirconium-copper-aluminum-nickel (ZrCuAlNi) offers an alternative method for creating smooth metal contacts, which lead to atomically smooth and uniform metal-insulator interfaces. This project aims to develop a method to sputter ZrCuAlNi from a target onto a silicon or silicon oxide substrate. Greater interface uniformity provided by amorphous metal contacts would produce devices that could be controlled with more precision and would behave predictably due to tighter control of the tunneling barrier. In turn, this would lead to better modeling of MIM diodes and a greater understanding of their performance and function allowing for further applications. In addition to a better understanding of MIM device function, nano-rectennas would benefit from better devices and more complete characterizations from the application of amorphous metal sputtering.

Transparent Multi-Layered Microstrip Patch Antenna

Lee, Eric

This study focused on the simulation of a transparent multi-layered microstrip patch antenna for integration into armor or vehicle windows, thereby reducing the visual signature of Army platforms. The initial design of the antenna was done using the Field Calculations for Bodies with Arbitrary Surface (FEKO) electromagnetic simulation suite. In order to achieve the required transparency, a sparse mesh pattern was chosen for the surface of the antenna. This mesh pattern was subsequently enlarged and repeated onto the ground plane, reducing the visual footprint of the antenna. The antenna design was built on layers of borosilicate glass and polyethylene terephthalate film, and implemented a strip feed and quarter-wave transformer for matched impedance and improved electromagnetic efficiency. After initial simulations, all antenna and mesh dimensions were optimized for a 1.5 GHz operating frequency. After the initial design was completed, a prototype patch antenna was printed onto a single layer of borosilicate glass and prepared for anechoic chamber testing.

Image Scale Estimation Using Nonlinear Least Squares

Lee, Joseph

For certain image-processing tasks, such as super-resolution, precise image scale estimation is required to obtain good reconstruction results. In this study, we assume that the two-dimensional translation and rotation parameters of a moving target are already known. Our approach models the relationship between a reference image and a scaled image based on the scale-space representation. The formulated model is nonlinear in the scale parameter, thus we use nonlinear least squares to estimate it. The proposed method consists of two steps: object segmentation and scale estimation. In the first step, we segment the object regions with a bounding-box using motion detection and edge features. After we obtain the rough size of the object images, we use the nonlinear least squares method to estimate the accurate scaling factor between the two images. We test the proposed method with simulated images at different scale and real image data.

Cannon-Launched Round Against a Concrete Masonry Unit

Ligda, Evan

In this project, the goal was to investigate the number of shots required to perforate a concrete masonry unit (CMU) with a double-reinforced concrete (DRC) stone pattern, using a cannon-launched round fired at 0° obliquity at a specific weapon to target distance. The experiment was performed at an outdoor range using a laboratory cannon barrel, with the team focusing on perforation of the wall. The team fired a total of six shots at different aim points—four being in the non-grouted section of the wall and two being in the grouted section—and found that every shot perforated the wall. Surprisingly, the results showed that the shots aimed at the grouted section of the wall perforated in the same manner compared to the shots aimed at the non-grouted part of the wall. The rebar was the sole part of the grout left intact after perforation. Measurements, notes, and pictures were taken after each shot, and were analyzed at a later date using Image Pro 6.3®.

Mechanical Property Variations of Nanocrystalline Tantalum Processed by High Pressure Torsion

Ligda, Jonathan

Using nanoindentation and microcompression showed that properties such as hardness, strength, and even deformation mode can change with position for tantalum (Ta) processed by high pressure torsion. Nanoindentation studies expose an increase in hardness with increasing radial direction, indicating a gradient in grain size and the possibility for changes in deformation mode. Microcompression tests show a switch from uniform deformation to localized plastic deformation as position changes.

Domain of Applicability of Peridynamics

Lucas, Richard

Peridynamics is a tool for analysis; its main goal is to overcome the limitations of classical continuum mechanics by modeling fracture without the use of external functions to govern the nucleation and growth of cracks. The purpose of my summer research appointment at the U.S. Army Research Laboratory (ARL) is to analyze peridynamics and determine its domain of applicability. The specific focus is to determine where peridynamics has some issues. I conducted two simulations with Emu and calculated an analytical solution of the deformation gradient using the peridynamics reformulation. Results show that there may be some error when using certain meshes with certain problems.

Raw Spectral Power Versus Weighted Phase Lag Index (WPLI) Analysis of Electroencephalography (EEG) During Shooting: Coping With Recoil Artifacts

Luo, Samantha

The U.S. Army is interested in studying the brain processes of Soldiers during real-life scenarios to better understand the neural communication among brain regions. This project uses a new functional connectivity measure, Weighted Phase Lag Index (WPLI), on electroencephalography (EEG) data collected from a Soldier in a shooting simulation. WPLI measures the phase difference between channel pairs, providing a means to identify zero-phase waves that can be caused by motion-induced volume conduction. The EEG data analyzed in this project occurs in the 2 s after a trigger pull, which includes a large movement artifact that results from the recoil of the rifle. The project compares the raw spectral power of the channel data to the WPLI analysis. This comparison shows that there are more significant windows from raw channel data than WPLI channel pairs in lower frequency bands and more significant windows from WPLI channel pairs than raw channels in higher frequency bands. This demonstrates that the two measures capture different elements of the recorded signal, and it suggests that WPLI can reveal neural communication among brain regions after removing large movement artifacts that exist as low frequency bands.

Improvements to PZT-based Radio Frequency (RF) Micro-electromechanical System (MEMS) Devices through Protective Atomic Layer Deposited (ALD) Coatings and High Temperature RF Transmission Lines

Magagnosc, Daniel

This study focused on improving lead zirconate titanate (PZT)-based radio frequency (RF) micro-electromechanical system (MEMS) devices through the development of an improved protective atomic layer deposited (ALD) coating for both preventing hydrogen damage in the PZT and protecting a silicon device layer from a xenon difluoride (XeF$_2$) etch release. Both thermal and plasma ALD coatings of aluminum oxide (Al$_2$O$_3$) and hafnium oxide (HfO$_2$) and combinations thereof were deposited and then tested by exposing the films to processing conditions present in the PZT MEMS fabrication process including solvent soaks, resist spin and develop cycles, and oxygen plasmas. In addition, alternative metallization layers were explored to extend the thermal survivability budget (>500 °C) of the co-planar waveguide transmission lines, thereby allowing improvements in the piezoelectric properties of the PZT. Using a combination of four-point probe resistivity measurements and optical imaging, combinations of titanium (Ti), platinum (Pt), chromium (Cr), and gold (Au) are explored to see if they have a transmission line metallization that can survive a 500 °C post-MEMS fabrication anneal.

Synthesis of Micro Aerial Vehicle Replicating Insects' Clap-fling Wing Mechanism Using a Single Biomorph Actuator

Maher, Mike

Certain insects use the clap-fling wing pattern to enhance lift forces. As the name suggests, the insect claps its wings together at the top of each upstroke, then flings its wings apart at the beginning of the down stroke. The end goal of the research is to create a micro aerial vehicle (MAV) that emulates a real insect in appearance, size, and functionality. This MAV would open the door to endless possibilities for reconnaissance and stealth operations, while, most importantly, keeping Soldiers safe at the same time. The current focus of this research is to try to reproduce the clap-fling pattern using wings modeled with computer-aided design (CAD) software, and a single piezoelectric actuator to reduce weight and power consumption. Different combinations of wing designs, mechanical amplification scheme, flap angle, wind speed, and actuation frequency are being tested in order to find an optimal configuration to increase lift or thrust. Thus, fabrication and testing are still underway, but the current results look promising. Further experimentation is needed in order to gain more in depth results, as well as possible improvements.

Optimal Sensor Placement for Intruder Detection: New Design Principles

Malik, Waseem A.

In this paper, we consider the problem of centralized detection of an intruder, which occurs uniformly on a specified set of points using an optimally placed team of agents. These agents make conditionally independent and identically distributed observations. Measurements are assumed to be noisy, with detection probability P_a and false alarm probability P_b. We formulate the problem as an M-ary hypothesis testing problem, jointly optimizing the agent placement and detection policies at the fusion center. Properties of the optimal solution are characterized using majorization theory. We prove that the uniform agent placement is never strictly optimal when the number of agents (M) equals the number of placement points (N). We also prove that for N_1, $N_2 > M$ and $N_1 < N_2$, both (M,N_1) and (M,N_2) have the same optimal solution structure. For a fixed P_a and increasing P_b, the optimal solution occurs nondecreasingly on a majorization-based scale for $M \leq 5$. For $M > 5$, this result does not necessarily hold, and we provide a simple counterexample. It is proved that the set of optimal placements for a given (M,N) can always be placed on a majorization-based scale.

Synthesis and Transfer of Pristine Graphene for Transparent Electrode Applications
Martin, Josh J.

Highly ordered, free-standing titanium dioxide (TiO_2) nanotube (TNT) arrays have been of intense interest in the alternative energies field in recent years due to their barrier-free electron conduction pathway versus TiO_2 nanoparticles in dye sensitized solar cell (DSSC) designs. TNT arrays prepared by electrochemical anodization of titanium (Ti) foils and combined with a transparent, indium tin dioxide coated polyethylene terephthalate (PET) film are attractive candidates for efficient, flexible DSSCs. Flexible solar cells offer great benefits because of the potential for low-cost, roll-to-roll production and the increase in applications due to superior robustness. This approach uses a two-step anodization procedure coupled with implementation of a rapid inert gas dehydration and ultrasonic agitation detachment method. By controlling the reaction conditions during anodization (voltage, duration, and concentration), TNT arrays with specific morphology, lengths, and diameters can be tailored to satisfy a particular application such as incorporating specialized protein dyes, in particular, bacteriorhodopsin (bR). The free-standing arrays, comprised of hexagonally closed-packed and regularly ordered TNT membranes, have been synthesized and detached from the original Ti substrate. Once the TiO_2 sol-gel is created, the free-standing arrays will be attached to the flexible PET film for improved photovoltaic properties and overall performance.

Locally Adaptive Contrast Enhancement and Dynamic Range Compression

Maschal, Robert

In surveillance applications, the visibility of details within an image is necessary to ensure detection. However, bright spots in images can occupy most of the dynamic range of the sensor, causing lower energy details to appear dark and difficult to see. In addition, shadows from structures such as buildings or bridges obscure features within the image, further limiting contrast. Dynamic range compression and contrast enhancement algorithms can be used to improve the visibility of these low energy details. In this paper, we propose a locally adaptive contrast enhancement algorithm based on the wavelet transform to compress the dynamic range of images, as well as increase the visibility of details obscured by shadows. Using an edge detector as the mother wavelet, this algorithm operates by increasing the gain of low energy gradient magnitudes provided by the wavelet transform, while simultaneously decreasing the gain of higher energy gradient magnitudes. Limits on the amount of gain imposed are set locally to prevent the over-enhancement of noise. The results of using the proposed method on aerial images show that this method outperforms common methods in its ability to enhance small details, and also prevents ringing artifacts and noise over-enhancement.

Data Structure Evaluation for Real-time Ray Tracing on a Graphics Processing Unit (GPU)

McCartney, Joshua

The purpose of this experiment is to evaluate different data structures that will be used to perform ray tracing on a general-purpose graphics processing unit (GPGPU). This ray tracing can be useful in such situations as determining a path through hostile territory that minimizes exposure to ballistic threats. The software that the Army currently uses for this task is not without its limitations. A path is hard-coded into the program, and the scene itself is static. The static scene is fast, but it falls short in the context of real-time ray tracing. Each frame takes a couple of seconds to process and overlay the ballistic threat. Here we compare the performance of a quad tree to a kd tree for dividing the space up into smaller subspaces for processing. This is just a step toward ray tracing in real time.

Dioxygen Reduction Study of Metals Supported on Nitrogen-Doped Carbon Materials in Alkaline Media for Portable Fuel Cells

McClure, Joshua P.

Anion exchange membrane fuel cells use OH$^-$ conducting polymer electrolytes to separate the anode from the cathode, which allows for less expensive non-platinum-group-metal (PGM) electrocatalysts for the oxygen reduction reaction. Nitrogen-doped graphene-like materials have been given attention as potential non-PGM electrocatalysts, and in this study, a radio frequency (RF) plasma-enhanced chemical vapor deposited (PECVD) process is used to grow carbon nanowalls (CNWs). Both CNWs and other graphene-like materials are doped using N_2 RF PECVD. Nitrogen incorporation is verified using x-ray photoelectron spectroscopy, and micro-Raman spectroscopy is used to probe the defective nature of the different carbon materials. A rotating ring disk electrode (RRDE) is used to probe the dioxygen reduction behavior of these developed materials in alkaline media, and it is found that there is a slight positive shift in onset potential of both the solution-based and PECVD-grown materials. To increase the electrocatalytic activity of these carbon materials, Ag and other metals are deposited onto these supports and studied using RRDE to obtain the mass activity and number of electrons transferred per O_2 molecule. The addition of Ag to the surface of these materials is pursued using three different methods that all show near four-electron reduction of O_2 to OH$^-$.

Microscale Integrated Power Inductors

Meyer, Christopher D.

In order to realize compact, mm^3-scale power management and conversion systems, microscale integrated power inductors need to be developed that can provide high density magnetic energy storage with high efficiency conversion between magnetic and electric energies at frequencies >50 MHz. The U.S. Army Research Laboratory's (ARL) previously published results demonstrate that air-core passives can fulfill these requirements by leveraging a multilevel thick-film microfabrication technology. To improve performance at higher current levels, this work reduces the electric resistance of the microinductors by extending threefold the layer thickness capability of the technology. Achieving high aspect ratios of up to 10:1 per layer enables the new passives to retain high inductance densities >100 nH/mm^2 while measuring 3–5 times lower values of resistance compared to the previous generation. However, a greater increase in the effective resistance of the thicker traces is observed at high frequency AC excitation. Comparison to models developed for bulk-scale wire-wound passives suggests that the increased AC resistance is attributable to the proximity effect.

Design of an Ultra-portable Android-based Rapid Field Diagnostic Suite for Mild Traumatic Brain Injury

Mikkilineni, Sohan

Blast-induced Mild Traumatic Brain Injury (mTBI) is a widespread battlefield hazard for American Soldiers that often goes undiagnosed. The detection of mTBI symptoms within 2 h of blast exposure can greatly reduce or eliminate permanent neurological damage by advising Soldiers to avoid further shocks. However, current systems for diagnosis rely on very heavy machinery and expert personnel, which are not suitable for rapid field diagnostics. A small handheld device, like a smartphone, would perfectly suit the limitations of field service. Smartphone devices provide a host of features in a small footprint, including on-board sensors such as cameras, accelerometers, and gyroscopes, which could be used to provide data for an automated diagnostic system.

This effort has contributed to the development of BrainAid, a mobile rapid field diagnostic suite (RFDS), which is built on the open-source Google Android operating system. BrainAid incorporates a wide variety of motor skill, stimulus response, and neurophysiological tests to better estimate a diagnosis of mTBI and damage location.

Illustrating Neuroscience Concepts

Mitchell, Lila

The many complex ideas and concepts in neuroscience can be easier to understand by those outside of the field if they are supplemented with visual representations that help define these ideas. However, it may be difficult to convey ideas dealing with complex neuroscience applications (e.g., brain-computer interface). This summer, my task with the U.S. Army Research Laboratory's Translational Neuroscience Branch was to create visual illustrations that provide a clear explanation of several complex neuroscience ideas, including translational neuroscience, brain interconnectivity, brain-computer interface, and Soldier fatigue. This paper focuses on the creative process I used to produce these illustrations, and some of the problems I encountered in creating these images.

Examining a Terrorist Network Using Contingency Table Analysis

Moore, Allison

The information revolution of the 21st century has changed the nature of war to focus on the area of network-centric warfare. While the number and strength of dark networks continue to increase, the U.S. Department of Defense seeks to identify, predict, and counteract possible terrorist threats. The intelligence community is undertaking the seemingly impossible task of using the information that is currently available through social networks and military reports. This paper will examine the Ali Baba data set that was created in 2003 for the National Security Agency (NSA) by Mark Jaworoski and Steve Pavlak. The Ali Baba data set contains fictitious Word documents that have recorded the actions of a suspected terrorist network. This paper demonstrates the use of statistics in examining terrorist organizations. Specifically, it determines if contingency table analysis using the R programming language can be used to analyze a terrorist network.

The Need for Quantum Repeaters

Moore, Tyrnita

Future quantum communication channels will allow quantum information to be transmitted and received with an exponential advantage over optical communication networks. However, quantum signals are very fragile because of the difficulty in maintaining the entanglement of quantum particles, such as photons and atoms. This paper discusses quantum repeaters that use entangled photons to couple quantum memories. This state-of-the-art technology will provide a new capability to move quantum information from one location to another without destroying the quantum entanglement property. Quantum repeater research will be the foundation for practical implementation of the quantum internet and quantum teleportation.

Soft Polymer Development for Robotics Application

Morton, Jeffrey; Mrozek, Randy; Lenhart, Joseph

Soft materials advances are critical for enabling future biomimetic robotics, including (1) the development of a flexible and elastic body that is tough and durable; (2) the incorporation of controlled adhesion mechanisms, and adaptive appendages and bodies for traversing difficult terrain and performing complex functions; (3) the design of soft actuators or artificial muscles that can move the robot reliably with low power input; and (4) the integration of flexible sensors and electronics to provide information gathering capability, environmental recognition, and stimuli-responsiveness. The focus for this summer is to determine the impact of incorporating thermoplastic elastomer gels into a carbon fiber lay-up to produce a composite material that remains flexible, while enhancing the toughness and durability. Specifically, the impact of processing conditions and gel formulations will be explored to determine the impact on the mechanical properties and identify opportunities to produce an adaptive response for integration into robotic spines and appendages.

Decohesion Energy of RDX

Munday, Lynn

The mechanical properties of molecular crystals are heavily influenced by their underlying crystal structure. Crystal engineering approaches have been used to tune these properties at the molecular or lattice level to affect the initiation sensitivity of energetic crystals and the tabletability of pharmaceutical crystals. Several atomistic methods exist to study mechanical properties in atomic and metallic crystals, such as ductile and fracture properties. In this work, we extended these methods to the more complex structure of a molecular crystal where molecules, instead of single atoms, fill the lattice sites. In particular, we developed a method to determine the energy required to create a free surface in the energetic molecular crystal αRDX. The free surface energy is then compared to the energy required to emit a dislocation to determine if the material plane is brittle or ductile. Results will be discussed in the context of experimental data and the crystal structure.

Abstract Statistical Cut Resistance of Single Kevlar Fibers

Nenno, Paul

Statistical studies have been conducted that concern the cut resistance of single Kevlar K129 filaments. Relationships between failure force and angle of incidence (both longitudinal and transverse) have been investigated. Angle of incidence was manipulated in the transverse (blade) and longitudinal (fiber) directions. Longitudinal cut testing showed a decreased Weibull modulus when compared to normal angle cut tests. Transverse cut testing showed the lowest Weibull modulus out of both the longitudinal and normal cut testing results. Results indicate that the highly anisotropic structure of Kevlar fibers encourages failure when subjected to a cut with a transverse angle of incidence.

Covert Line of Sight Communications Employing High-powered RGB Light-emitting Diodes (LEDs)

Olver, Ian

The advent of light-emitting diode (LED) lighting makes possible the development of dual-use systems that provide illumination as well as covert line-of-sight communications. One scheme, based upon color-shift keying (CSK), involves separately modulating the red, green, and blue components of an RGB-based white LED without changing the perceived average color of the emitter to an observer. In this paper, I discuss the development of a test bed for evaluating the performance of different constellations of symbols within a CSK visible communications link. The test bed consists of a paired transmitter and receiver for each channel (red, green, and blue) as well as a computer interface for synchronously driving the transmitter and monitoring the receiver. The receiver consists of a photodiode that drives an integrator circuit that records the total on-time of a channel during the symbol period, $1/f_s$, where f_s is the frequency of the communications link. The goal of this system is understanding the tradeoff between communication frequency and constellation size and placement. I discuss the technical challenges in demonstrating an RGB transmitter and receiver operating at a symbol frequency up to 333 KS/s, including synchronizing the transmitter and receiver clocks and distinguishing between different symbols.

Automated Fabrication of Nanoscale Tension and Compression Test Samples at Multiple Positions Using the Focused Ion Beam (FIB)

Onate, Francis Ryan

Tension and compression test samples from different materials and of different sizes can be created manually using individual scripts. A program called AutoMike[6] creates thinned compression pillars in a single position on a bulk sample. The objective of this project is to create a program called AutoFrancis that automates the creation of test pillars at different positions with different sizes on the bulk sample. AutoFrancis provides the user with a series of dialog boxes that allows the user to select specific inputs to execute the program. These dialog boxes will guide the user to save positions where the pillars are to be created.

AutoFrancis will reduce the man-hours required to create the test samples by eliminating constant observation from the user as the test samples are created. AutoFrancis comes with a document that will contain information that will help users, as well as developers, to better understand the structure of the program. This paper contains useful diagrams and graphs to guide users in operating the system and developers in maintaining the source code.

Optimizing Strategies for an Observation-Nudging-Based Four-dimensional Data Assimilation Forecast Approach with WRF-ARW

Pattantyus, Andre

The Weather Research and Forecasting (WRF) model is an open-source numerical weather prediction model with numerous features, such as the four-dimensional data assimilation system, an option to nudge forecasts to observations in order to improve forecast quality and performance. This process can act as a dynamical initialization prior to the forecast period to reduce errors that result from interpolation across the grid. For data void regions, assimilating observations from a temporary network could vastly improve forecasts in the region. However, users must specify how much influence each observation will get in the model and over how large an area each observation will influence. These weighting factors will have a great effect on the forecast quality. This research attempts to determine the optimal setting of the radius of influence for upper air and surface observations within the assimilation system. A case study over Yuma, AZ, is examined in which a low-pressure system produced dynamic and orographic precipitation across the region. Observations from the U.S. Air Force in Yuma will be assimilated into Weather Research and Forecasting for the 06 coordinated universal time forecast for an entire 24-h forecast cycle. Results suggest upper air observations have a greater impact on forecast accuracy given a large radius of influence.

Electrical Passivation of Anti-reflective Microstructures in Mercury Cadmium Telluride

Pattison, James

Inductively coupled plasma (ICP) etching was applied to create anti-reflective (AR) structures in mercury cadmium telluride (HgCdTe or MCT). These high-aspect ratio microstructures present a challenge to conformal deposition of passivating materials, which was accomplished through atomic layer deposition (ALD) of aluminum oxide (Al_2O_3) and silicon dioxide (SiO_2) layers. Scanning electron microscopy was used to characterize the microstructures after an ICP etch and again after ALD. Infrared reflectance and transmission measurements were performed on as-grown, ICP-etched, and ALD-passivated samples to demonstrate an increase in absorbance due to the AR structures. Planar sister samples of MCT were exposed to similar ICP etch conditions and passivated by ALD. The electrical passivation of the planar samples was studied through photoconductive decay (PCD) measurements in order to compare the minority carrier lifetime of as-grown, etched, and passivated material. Planar sample served as proxies for the etched material, as the required electric field of the PCD experiment does not pass through the anti-reflective microstructure layer.

Construction of a Boosted Cascade for Human Detection

Paxton, Christopher

Detecting humans in static images is a complex task that has been the focus of much recent research. Strategies involving the combination of multiple simple features have proven effective as an approach for improving the accuracy of human detection. Along these lines, this paper proposes a framework in which target windows are evaluated through a rejection cascade. Each level of the cascade is composed of multiple linear support vector machines (SVMs) representing different blocks of the target window. These blocks are determined by AdaBoost and weighted according to their accuracy, similar to previous studies using histograms of oriented gradients (HOG) with rejection cascades. As a proof of concept, cascades were trained with color and grayscale HOG features, and color frequency bins were added to the feature vectors. Results of the test showed that the addition of simple features to the cascade vector can decrease the number of SVMs needed to classify a window as containing a human, meaning that this approach can be used to build fast, robust SVM-based rejection cascades for human detection.

Investigation of Surface Display Systems for Synthetic Recognition of *Staphylococcal enterotoxin B*

Pennington, Joseph

The rate a which the Army needs to produce a biological recognition element in response to new and emerging threats far exceeds current antibody development capabilities. Synthetic recognition alternatives including peptides (the building blocks of antibodies) have the potential to address this need. Peptide libraries can be displayed in both yeast and bacterial surface constructs, each having a particular advantage in production and overall binding performance. Each method involves sorting the library by magnetic sorting (MMS) followed by characterization of the individual clones by flow cytometry. In this work, we aim to get a better understanding of the molecular recognition from both constructs determining and ultimately using the advantages and disadvantages of each display system, which are critical to producing a biosensor with the highest affinity and specificity in the shortest amount of time. The target chosen to test each method is *Staphylococcal enterotoxin B* (SEB). SEB is a potential biological weapon due to its high thermostability as well as the ease of which it can be aerosolized. Determining the advantages of each surface display system will allow quicker development of new biosensors and shorten the time required to detect new threats.

MUVES-S2 Lethality Analyses and Comparison Between the Operational Requirement-based Casualty Assessment (ORCA) and the Sperrazza-Kokinakis (S-K) Methodologies

Ploskonka, Ann

Survivability/lethality/vulnerability (SLV) analysis of U.S. Army combat systems is performed using MUVES-S2, a computer model capable of evaluating the effects of one or more munitions against any defined target. Historically, MUVES-S2 has analyzed personnel casualty using the Sperrazza-Kokinakis (S-K) methodology; however, the Operational Requirement-based Casualty Assessment (ORCA) modeling system is being integrated into MUVES-S2 analyses in place of the S-K approach, because it has been shown overall to be a more comprehensive methodology for analyzing personnel casualties. To further investigate the differences in the methodologies in a lethality analysis, two targets and three threats were chosen and run in MUVES-S2 using the ORCA methodology. The same threat and target combinations also were run using the S-K methodology and the results were then compared to determine the differences in the level of detail and accuracy between the two methodologies.

Development of a Novel Experimental Technique for Gels using Airburst Loading from Gas Gun

Pritts Jr., James

A novel experimental technique was designed and developed to test gels at different pressure rates. A gas gun was modified to house pressure transducers and a gel specimen holder was integrated into the gun tube. A proof of concept was conducted using PermaGel™ samples and full-field displacement/strain measurements were acquired from digital image correlation (DIC) techniques. The experimental setup is presented along with an explanation of the procedure.

DNA Thin-film Materials

Proctor, Thomas J.

In today's Army, there is a pressing need to improve the qualities of electronics. Some requirements include making electronic devices that are cheaper, smaller, and lighter, while still maintaining or even expanding their technical capabilities. One other aspect of importance is ―green" power, and renewable energy is very promising due to its abundance and ability to be harvested cheaply. At the U.S. Army Research Laboratory (ARL), research is being done to meet all of these requirements. One example of this research is using deoxyribonucleic acid (DNA), currently salmon sperm DNA, to create thin-film membranes that will eventually be used in electronics. This can be done by using a surfactant (CTAC) to cause the DNA to separate and precipitate out of solution. Then, the DNA is redissolved in a solvent and spin-coated on to a silicon (Si) wafer to create the thin film. At this time, work is being done to optimize all components used to make the film membranes the best as possible. These optimal components include technique, spin-coat speed, solvent, and types of DNA used. If done successfully, these materials may be used in the alternative power supplies that meet all of the proposed requirements.

I wish to acknowledge the mentorship of Amy Finch.

Personnel Injury Analysis of a Small-arms Threat to Various Body-armor Protection Levels

Racine, Michelle

This analysis investigates the difference in the protection various body-armor protection levels provide against a small-arms threat. The protection differences are analyzed using MUVES-S2 with the embedded Operational Requirement-based Casualty Assessment (ORCA). Each protection level was modeled using BRL-CAD$^{©}$ and the MUVES-S2/ORCA model and then compared the ballistic protection provided by each protection level against small-arms threat at various ranges. Significant injury probabilities were determined for each body-protection level. The resulting data are organized and presented in graphical representations that allow for easier viewing. Conclusions and observations are then made for this piece of analysis, which is part of a much larger effort within the U.S. Army Research Laboratory (ARL).

Investigating Supercapacitor Performance of Graphene-based Powders

Raju, Vinay

Supercapacitors are electrochemical energy storage devices that are renowned for high energy density compared to other capacitors and high power density compared to batteries. Graphene, a single atomic layer of the compound graphite, has the potential to store high amounts of energy. This research deals with maximizing capacitance for graphene-based supercapacitors. A new electrochemical characterization technique was explored to expedite our characterization of the graphene, based on a one in which carbon powders are packed into an etched platinum microdisk electrode for characterization. My experiment investigated using a nickel wire with a hole drilled in the end as a lower-cost alternative. To validate its effectiveness, the microelectrode method was compared to the drop-casting method. The drop-casting method requires first making the graphene into a liquid solution and then evaporating away the solvent, leaving the graphene on the electrode. A wide range of capacitance variation was observed between these materials due, in part, to variations in their electrical conductivity. Overall, supercapacitor research has a long way to go in determining how to meet the energy needs of our Soldiers.

Small Unmanned Ground Vehicle (SUGV) Control: Bridging Robot Operating System (ROS) to Joint Architecture for Unmanned Systems (JAUS)

Rao, Chirag

U.S. Army Research Laboratory researchers have been keen on employing autonomous functionality on iRobot's Small Unmanned Ground Vehicle (SUGV). To do so, a software bridge must be designed so computers using a Robot Operating System (ROS) may send and receive messages from the SUGV, which communicates via the Joint Architecture for Unmanned Systems (JAUS) messaging architecture. The ROStoJAUSBridge program meets this interfacing criterion and makes way for off-board computers to gain control of the SUGV's mechanical components and accessory devices. The first step toward building the bridge was establishing network communication with the robot. The next task was to parse messages sent from the robot, e.g., odometry, velocity, and local pose information. Finally, publishing and subscribing classes were made to handle communication with ROS, so that ROStoJAUSBridge could broadcast SUGV information to ROS programs and vice versa. ROStoJAUSBridge paves the way for researchers to apply programs, such as waypoint navigation and autonomous exploration, on the robot platform. In the future, researchers will be able to receive video image data from the SUGV.

Weighted Phase Lag Index (WPLI) as a Method for Identifying Task-Related Functional Networks in Electroencephalography (EEG) Recordings during a Shooting Task

Rawal, Sandhya

Weighted Phase Lag Index (WPLI) is a methodology used to identify nonzero phase lag statistical interdependencies between electroencephalography (EEG) time series from pairs of electrodes. Identifying nonzero phase lags may be useful to identify neural interaction among regions based on the known delay for brain region-to-region communication. This project applies WPLI analysis to previously collected EEG data from a Soldier performing a shooting task. WPLI was examined on EEG data epoched around trigger pull events, which include both brain activity and movement artifacts from weapon recoil. This functional connectivity measure was compared to a traditional time-frequency analysis at individual electrode sites. In the individuals studied, WPLI identified a left lateralization in the network communication as well as neural activity from the occipital electrodes. Both findings were not evident in the channel-based analysis. This project suggests that WPLI may be able to detect task-related functional networks, despite artifactual contamination that is typical in real-world environments.

Electroencephalography (EEG) Filter Design for Near-real-time Signal Processing

Reid, Cordell

Electroencephalography (EEG) uses a set of electrodes to measure voltages in the brain produced by the synchronous firing of thousands of neurons. EEG is a noninvasive, low-cost method to study brain activity. The low signal-to-noise ratio of EEG data prevents the use of the system outside of controlled laboratory environments. EEG analysis is further crippled by inconsistencies in data due to inter- and intra-personal variation. A filter that allows real-time, frequency-specific analysis of EEG data is a critical step in transitioning the technology from the laboratory to the field, enabling the practical study of Soldier cognitive function on a single-trial basis. Different filtering methods including simple and multistage bandpass filters and several transforms (Fourier, Hilbert, and Wavelet) are investigated through MATLAB testing of both simulated and experimental data in order to determine the optimal filter design. A MATLAB-based software package capable of interfacing with EEGLAB processing software will be developed for practical use. This software package will ultimately be realized in hardware to apply the system to the field.

Evaluation of Primers for Allele-specific Polymerase Chain Reaction (PCR) in Mixed Bacterial Cultures

Ren, Suelynn

Single nucleotide polymorphisms (SNP) are single mutations that can be used to determine whether or not a bacterium is virulent or drug resistant. Allele-specific polymerase chain reaction (PCR) is an assay used to detect such a mutation in a specific gene. Two subspecies, Detrick 1 and Detrick 2 of the Army model for anthrax, *Bacillus globigii*, were considered because they differ by a single SNP on one of their sporulating genes. This difference causes Detrick 2 to hyper-sporulate. In this study, we proceeded in two steps: first, we generated samples from the two bacterial strains with defined ratios of genomic DNA; second, we tested the ability of a set of primers to detect the presence of one of the genomes in the mixed samples and determine its relative amount. PCR was used to select one pair of primers, which successfully detected the Detrick 1 genomic DNA. The successful completion of this project will allow for more intensive competitive growth studies between differing bacterial strains.

Fast N-body Simulation with CUDA for Electroencephalography Analysis

Romero, Gregory

This summer at the U.S. Army Research Laboratory I was presented with some MATLAB code from the Human Research and Engineering Directorate. Several projects from the 2010 Neuroscience Director's Strategic Initiative were proposed that dealt with cognitive studies aimed to help understand a Soldier's mind on the battlefield. One of their proposed projects was ―Non-Linear Brain Activity in Real-World Settings: Movement Artifact and the Phase Lag Index." One method used to study this area of research is known as electroencephalography (EEG). Processing the data sets recorded using this method can limit computing resources in terms of memory and speed. The MATLAB code I received used EEGLAB—an interactive MATLAB toolbox from the University of California San Diego—which is designed to process continuous and event-related EEG data. My objective was to port this MATLAB code into C code and mimic its functionality using the Fast N-Body algorithm with CUDA on a graphics processing unit cluster.

I wish to acknowledge the mentorship of Dale Shires.

Assessment of Publicly Available Resources to Build an In-House Term Extractor

Rose, Gabriella

A domain-specific term base is a list of vocabulary relevant to a particular domain. This term base is important not only as a resource for written and verbal translation but also as a foundation for natural language-processing applications, such as automatic summarization and information/relationship extraction. A domain-specific term base can be extracted automatically from documents representative of the domain. The idea behind automated term extraction is to compare the term frequency of a candidate term in a document with its frequency in everyday language. This would evaluate whether a term is more specialized or more appropriate in a general domain.

The current investigation is designed to determine the best process for creating a term base for a particular document by analyzing different public online extraction tools: Maui, TerMine, Alchemy API, Sokeywordanalysis, and Translated Labs. In this study, a military technical document, the Rifle MMS Manual, is examined, and each text extraction utility is compared with a preconfigured glossary formulated by our subject-matter expert. Once a public text miner is found that most closely approximates the human-formulated glossary, it is employed to explore a second military technical document, Field Manual 7-8. To determine the appropriate glossary length in future projects that involve the military technical domain, such as the FM 7-8, I use the proportion of key words to the number of document words that were identified by the subject-matter expert. Since there were 48 key terms identified by the expert and the Rifle MMS document is composed of 1081 words, the proportion to words per document is 0.0444 key terms per 1 word.

Mechanical Testing and Evaluation of Different Weave Patterns in Composite Materials

Rossino, Nicholas

In an effort to research the suitability of a vast variety of composite materials for Army applications, a database has been generated to hold the mechanical properties of various types of composites. More specifically, fiberglass reinforcement with different types of weave patterns and an epoxy matrix are evaluated for the database. The vacuum assisted resin transfer molding (VARTM) method is used to manufacture each composite. The composite material used is an E-glass/SC-15 system with differing weave patterns. The material's properties were gathered using various mechanical tests; four main tests were performed: tensile, short-beam shear, compression, and flexure. All tests were performed in accordance with ASTM specifications. Additionally, drop-weight impact, Boeing compression after impact, and burn-out tests were performed to gather specific data for each composite system. The results of these tests will be recorded in order to establish a baseline data set in database records that will be available throughout the Department of Defense. The initial development, methods or processing, and other key characteristics will be controlled in order to create traceable standards that allow cross-facility comparisons to be reliably performed in the future.

I wish to acknowledge the mentorship of James Sands.

Analytical Measurements on Ducted Rotors for Unmanned Aerial Vehicles (UAVs)

Roustopoulos, Theo

An analytical investigation was conducted to determine the lift and drag coefficients, as well as the lift and drag forces, across a ducted lift fan for its integration in unmanned aerial vehicles (UAVs) using the computational fluid dynamics (CFD) capabilities of SolidWorks software. The analysis was broken up into two parts—the analysis of the ducted fan and the analysis of various NACA0015 orientations. The ducted fan, modeled using SolidWorks, was fitted with an idealized rotor with a prescribed fan curve to ensure controlled behavior and simple mesh refinement for quick processing time. We observed that the shape of the duct had a strong influence on the drag that the ducted rotor assembly experiences without sacrificing lift. The same analysis was also conducted across SolidWorks models of a NACA0015 airfoil at different angles of attack and twists in order to assess the accuracy of the CFD software; we ultimately gained a better understanding of the flow behavior across an already existing fan blade with a varying chord length and pitch. Generally, we observed that the simulations revealed an error of about 15% compared to the experimental data.

Integrated Thin-film Piezoelectric Traveling Wave Ultrasonic Motors

Rudy, Ryan

An integrated approach to the fabrication of thin-film piezoelectric traveling wave ultrasonic motors (USMs) at the millimeter-scale is being developed for low power, high torque motors for small-scale robotics, biomedical, and sensing applications. This paper describes the realization of ultrasonic motor stators ranging in diameter from 1–3 mm using wafer-scale micro-electromechanical system (MEMS) fabrication techniques with lead zirconate titanate (PZT) thin films. Using laser Doppler vibrometry (LDV), controlled traveling waves were demonstrated in the bulk silicon elastic medium of the stator and the standing wave behavior was characterized for control purposes. Furthermore, the resonant modes of the fabricated stators were modeled using finite element models, and the experimental results agree well with this analysis.

Helium Loss and Vibration Isolation in a Magnetic Resonance Force Microscopy (MRFM) System at 4 K

Rushing, Samantha

The construction of a new magnetic resonance force microscopy (MRFM) system is described. We discuss our success with using extruded polystyrene (Styrofoam) to fill the neck of the Dewar to minimize the loss of liquid helium (He). The system is designed to minimize mechanical vibrations of the MRFM probe head, hence limiting interference from environmental vibrations. The isolation is achieved by suspending the MRFM probe head from three springs. We are designing several passive solutions to isolate the vibrations. We want to measure the limitations of passive vibration control solutions to determine if the use of active systems to control vibrations below 10 Hz is warranted. Initially, we will compare the use of Teflon and metal springs used to suspend the probe head.

Pyrolysis Condition Effects on Orientation of Sol-gel PbZr$_{0.52}$Ti$_{0.48}$O$_3$ Thin Films

Sanchez, Luz M.

High {001} texturing at the morphotropic phase boundary of PbZr$_{0.52}$Ti$_{0.48}$O$_3$ (PZT) will show improvements in the dielectric permittivity and increases in the piezoelectric stress constant. This will result in substantial improvements in device performance, including lower actuation voltages, higher force actuation, and lower power consumption. Recent research at the U.S. Army Research Laboratory (ARL) has shown that with improvements to the bottom electrode, and through the use of PbTiO$_3$ seed layer, we can achieve 89.66% (001) orientation in PZT thin films. Optimizations of the rapid thermal annealing (RTA) conditions and Pb-excess of PZT (52/48) show 94% (001) orientation. The pyrolysis conditions of PZT films between 300 °C and 500 °C greatly influence the (111) and (100) orientations. X-ray diffraction data, scanning electron microscopy, and differential scanning calorimetry will give better insight to the orientation, grain size, and phase transition effects of pyrolysis temperature on our films.

Cyber Physical Sensing and Control: Circuit Implementation

Schneider, Kathryn

In this research, I will demonstrate circuit-level implementation of a bio-plausible ―slow computing‖ control theory that has been developed by the Murray Group at Caltech and, to date, demonstrated only in software. Professor Murray's approach to control theory performs tasks in parallel, with asynchronous timing, reducing the overall number of computations relative to standard control theory approaches. The implementation of this bio-plausible control theory promises to reduce the power required for information processing and decision making in power-constrained sensor array applications, such as micro autonomous robotics and textile-based sensing. In this research, an appropriate algorithm will be implemented in the design of a field-programmable gate array (FPGA) in order to validate the ―slow computing‖ control theory in a physical application for autonomous control. Simulation of the circuit will be performed in Cadence software, and a validation experiment using a multisensory emulation suitable for a small robotic platform will be designed.

Enhanced Target Tracking Through Infrared–visible Image Fusion and Contextual Information

Schnelle, Stephen

Video surveillance is an important tool for force protection and law enforcement, and visible and infrared video cameras are the most common imaging sensors used for this purpose. In this paper, we present a feasibility study on fusing concurrent visible and infrared imageries to improve the tracking performance of an existing video surveillance system. Image fusion was performed using multiple pixel-based image fusion algorithms, examining the detection and tracking performance of each. Five of the pyramid-based methods were shown to provide superior performance enhancements, three of which also managed to achieve it with relatively low computational costs.

Relevant contextual information, such as weather (by extracting archived data), time of day, and day of week of the input video sequences, were exploited to further improve the detection and tracking performance. Camera viewing angle and other metadata were also considered, but not much of these data were gathered concurrently during the data collection process. Due to the limited amount of data, conclusions regarding contextual performance are difficult to draw, though it does appear temperature has a slight bit of effect on detection. However, the type of event and the quality of sensor acquisition seem to play a much more substantial role.

Target Modeling for Ground Mobile Branch (GMB)

Schulz, Matthew M.

This paper documents my efforts and the insights I have gained while serving as a target modeler for the Ground Mobile Branch (GMB) of the Survivability Lethality Analysis Directorate (SLAD). In support of the Branch's role of providing modeling and simulation support through the ballistic analysis of current and future vehicular systems, my primary task was to gain knowledge and insight into the analysis process through understanding the role SLAD plays in the development of combat systems, specifically, how SLAD's analysis results leverage vehicle evaluation and assessment in order to lead to modifications, which will ultimately increase the survivability of a particular system. To achieve this, I participated in vehicle measurements using metrology equipment (using three-dimensional [3-D] BRL computer aided design (CAD) target geometries and the MUVES vulnerability model), supported target geometry development through the production of component parts, and observed various test-shots intended to produce data for use in MUVES analysis.

Characterization of the Phosphoketolase Pathway in *Clostridium acetobutylicum*

Shankar, Jaishri

Clostridium acetobutylicum is involved in fermentation of biomass, resulting in the production of organic solvents, specifically acetone, butanol, and ethanol. Once useful in the early 1900s, it has slowly regained prevalence as energy usage has increased and resources have become more difficult to obtain. Xylose, a pentose sugar, is particularly attractive as a feedstock for *C. acetobutylicum*, as it comprises 30% of cellulosic biomass. However, *C. acetobutylicum* grows extremely slowly on this substrate, and efforts to increase the speed would be advantageous. The metabolism of pentose sugars in *C. acetobutylicum* leads to a common intermediate: D-xylulose-5-phosphate. From here, most organisms use the pentose-phosphate shunt. *C. acetobutylicum*, however, appears to contain another pathway: the phosphoketolase pathway. This pathway offers an alternative route for pentose metabolism. The purpose of this study is to biochemically characterize the phosphoketolase pathway and attempt to engineer a strain of *C. acetobutylicum* that would induce the pathway in the presence of xylose.

Synthesis of Graphene-based Inks for Inkjet Printing

Shelburne, John

Graphene-based inks take advantage of the outstanding electrical properties of graphene. With its high electrical conductivity, this ink can be used in an inkjet printer to print antennas and other electrical components on a multitude of substrates. Micro-mechanical cleavage of graphite produces graphene with the best electrical conductivity, but is not easily scalable or useful for liquid solution. Chemical methods of graphene production, such as reduced graphene oxide, have been shown to reduce the electrical conductivity of graphene. Difficulties in graphene synthesis have led to new methods that produce high quality graphene with similar electrical characteristics to the micro-mechanically produced graphene sheets. One such method uses liquid phase exfoliation and stabilization of graphene nanoparticles by a surfactant or polymer in solution. So called ―pristine graphene" should have similar electrical characteristics to micro-mechanically cleaved graphene, as well as be suitable for use in an ink. This work focuses on the synthesis and structure-property characterization of radio-frequency-assisted exfoliation of expanded graphite, while maximizing electrical conductivity and printability.

I wish to acknowledge the mentorship of Kate Duncan.

Autonomous Self-righting for a Generic Robot on Planar Surfaces

Smith, Daniel Carlton

Robots are increasingly being used in search-and-rescue operations, reconnaissance missions, and combat situations. Unfortunately, many robots are subject to tipping over in these hazardous environments. Controlling the robot to successfully right itself can be a difficult and time-consuming task for operators, a major problem in situations that are already both time-sensitive and dangerous. Therefore, we propose a quasi-static computational approach to autonomous self-righting that is robust to planar surfaces, both level and sloped. By examining the location of the center of mass over the range of possible robot orientations and configurations, tip-over events are identified, forming the boundaries of sets of stable states. A directed graph is then created in which each set of stable states forms a unique node, and tip-over events mark the transitions between nodes. Costs are then assigned to the transitions based on the change in potential energy. Thus, graph navigation produces a series of motions that can be used to right the robot, and an analysis of the graph's reachability can be used to assess a given robot design's ability to self-right. This paper explains our approach in detail and provides a case-study demonstrating the validity of the approach.

Real-time Power-line Load Analysis, Detection, and Identification

Smith, Darren

Electric power lines generate significant electric fields due to the electric voltages on the lines and significant magnetic fields due to load currents. Leveraging data from phasor plots (a new way of displaying multiple dimensions of relevant data for load events and histories), the U.S. Army Research Laboratory (ARL) developed the Live Animated Multi Phasor (LAMP), a new tool for analyzing load events in real time that computes and displays phasors for streaming live power-line data. This paper describes new capabilities developed since its completion in 2010. Processing of multiple signals and harmonics simultaneously gives LAMP more relevant information for detecting and identifying events. A new event detection algorithm was developed based on the covariances of phasors. Events are detected by maximizing the statistical significance of potential state changes, allowing them to be classified or identified by combining seven dimensions of data and comparing them to known loads. LAMP was used in a recent field experiment to provide instant feedback and confirmation of valid data. Examples of real-world processing and results are demonstrated along with a summary of the library of events observed in the experiment. Finally, improvements and additions for LAMP are described for current and future work.

Composite Study of Modified Hummers and Liquid Phase Exfoliation Methods for Graphene Sheets

Squires, Kyle

The goal of this study was to compare the structure and properties of graphene obtained from two different methods, namely, (1) the modified Hummers method involving reduction of graphitic oxide and (2) liquid phase exfoliation of expanded graphite in solution. Graphene oxide has long been used to synthesize graphene-like sheets, but these sheets normally have many imperfections, which alter the particle's properties. The modified Hummer's method was used to synthesize graphene-like sheets ranging from 400 to 1200 nm in size. These sheets were found to have high resistivity. On the other hand, the liquid phase exfoliation method yielded pristine graphene, which had few impurities and superior mechanical, electrical, and thermal conducting properties. The two resulting particles' sizes were compared using two different characterization methods: particle-size analyzer and x-ray backscattering. Morphology and surface properties were characterized by a combination of atomic force (AF), scanning electron (SE), and transmission electron (TE) microscopic techniques. These studies allowed us to establish the relative merits of the two techniques in synthesizing high-purity graphene nanosheets. Preliminary results with the scanning ion occlusion sensing (SIOS) platform showed similarly sized particles between graphene oxide and pristine graphene, but more testing is required.

Development of First Generation Nanoenergetic Fluidic Jet Generators

Staley, Clay

We present the fabrication, assembly, and packaging of first-generation nanoenergetic fluidic jet generators. The generators consist of an energetic material chamber, elastic membrane to serve as a piston, and a vaccine reservoir, all tightly bonded in a self-contained device using micro-electromechanical system (MEMS) processing techniques. Maximum deformation lengths of the polydimethylsiloxane (PDMS) membranes are characterized as a function of PDMS diameter, PDMS thickness, energetic material composition, and energetic material mass, using high-speed photography and as compared with theoretical calculations. Assembled nanoenergetic fluidic jet generators are analyzed to extract critical operation parameters, such as fluidic jet velocity, ejected jet diameter, penetration depth, and fluidic dispersion using in air jet velocity measurements and ballistic gel penetration characterization. Performance scaling laws have been established to determine design parameters for smaller future generation devices.

VCON2 Prototype Circuitry Housing Design

Stephey, Tyler

The purpose of this design project was to create a mechanical housing for the VCON2 sensor and circuitry array. Since this was a prototype design, the focus was on production cost and simplicity of use and construction. The VCON2 apparatus is intended to be buried and left to autonomous operation, and for this reason, the container needed to be tightly sealed to keep possible contaminants out; yet, the device needed to be easily accessible in order for fast repairs to be made. Cost was minimized by using standard size aluminum (Al) tubing instead of custom made boxes to hold the batteries, and by finding as many stock parts for the container as possible. The design itself was made more simple and user-friendly by providing easy access to the sensor circuitry stack by mounting it within the housing so that it can be removed as one stacked unit. The latches are also simpler than those previously considered and are less likely to break. Finally, the components holding the container together have all been selected so that the only tool required to access the inner circuitry is a wrench. The prototype has yet to be constructed, so the effectiveness of the design has not been seen.

I wish to acknowledge the mentorship of Mr. Brian Mary.

Raman Spectroscopy of Graphene

Tan, Cheng

The metrology and analysis of graphene materials for bolometry device applications is performed in this work. Graphene thin films grown by chemical vapor deposition (CVD) on metal substrates are characterized by Raman spectroscopy measurements, producing a two-dimensional array of spectra with characterizing peaks. Using the analysis software provided with the Raman spectroscopy tool, the results of the scans are evaluated at characteristic peaks, which are then used to study the graphene/substrate interaction. The characterization allows for potential evaluations, such as identifying possible grain boundaries and defects, as well as determining the number of graphene layers existing on the substrate. These analysis results can then be used in statistical calculations, creating a quantifiable method of metrology.

Computational Data Extraction and Image Processing of Spark Shadowgraphs

Tipton, John

I performed an experiment to determine whether image processing software can be used to replace the manual reading of spark shadowgraph images. The project consisted of developing three programs. The first program involves code development to batch scan film containing spark shadowgraph images at high resolution using a Vidar DiagnosticPro Advantage© scanner. A second program enables the user to rename the images and orient them for processing. Finally, the measurement extraction (third) program uses the National Instrument Vision Development Module image processing techniques to extract critical information from each image. The data collected as a result of this procedure includes projectile position and angular orientation as measured at each station number. This data is used by the Aeroballistics Research Facility Data Analysis System (ARFDAS) to track and analyze projectile flights and develop aerodynamic coefficients. At this time, the first two programs are complete. Work on the third has been initiated and preliminary results have been obtained.

Investigating a Drop-On-Demand Microdispenser for Standardized Sample Preparation

Tober, Keeley Q.

The range of fabrication methods used for preparing energetic samples results in widespread variability and reproducibility challenges, thus making it increasingly difficult to evaluate chemical detection technologies. To overcome these challenges, we are examining the optimization, characterization and calibration of droplets from a drop-on-demand microdispenser that is appropriate for the preparation of energetic reference materials. Droplets are monitored by an observation camera with a synchronized strobe, and the reproducibility of drop size and volume is optimized by adjusting the piezoelectric waveform parameters. Device settings are determined for optimal droplet formation and velocity. In current research, droplet diameter and uniformity were measured using fluorescence microscopy and ultraviolet-visible (UV-Vis) absorption spectroscopy. The results presented here demonstrate the operational factors that influence droplet dispensing for specific materials (e.g., energetic and interferents). Understanding these parameters allows us to investigate droplet and sample uniformity and reproducibility (typical calibration goodness of fit values of 0.991 and relative standard deviation ≤5%), and thus develop a successful and robust methodology for energetic sample preparation.

Foundation of a Heterogeneous Electronics Integration Platform

Trocchia, Scott

Due to the increasing complexity and size constraints of electronics, no single monolithic technology can adequately realize the full spectrum of Army-related applications. The integration of a wide range of devices, each fabricated in different technologies and performing a well-defined task, would enable the construction of high performance systems. We use a custom microfabrication process flow to specify how to manually drop arbitrary die into 500-μm-deep cavities and have them interface with each other. A high quality factor (Q), state-of-the-art copper (Cu) electroplating process will be combined with the chip pick-and-place strategy, with the goal of achieving a flexible and expandable plug-and-play platform. This circuit architecture approach permits high density interconnects, reduces pad parasitics, and allows researchers to construct highly miniaturized, integrated platforms for components that would otherwise solely be measured on probe stations. Future work will include testing and characterization of prototype heterogeneously integrated designs.

Characterization of Electrostatic Multilayered Bacteriorhodopsin Films

Tumlin, Travis

Multilayered assemblies of bacteriorhodopsin (bR) and poly(dimethyldially)ammonium chloride (PDAC) have been made using electrostatic layer by layer deposition. Layer by layer deposition is made possible based on the oppositely charged solutions. Subsequent dipping allows for a controlled number of layers with relative precision. Characteristic measurements have been made to ensure the correct ordered deposition for each layer and the photovoltaic properties for each layer. With these measurements, it was apparent that the photovoltaic characteristics of the bR were kept intact and even enhanced with multiple layers. It was found that the increase in layers results in an increase in absorption around the 570 nm wavelength. This is consistent with baseline bR ultraviolet-visible (UV-Vis) measurements. Based on these findings it is feasible to create nanobiosensors that can be created using the bacteriorhodopsin protein.

Development of a Lumped Element Circuit Model for Approximation of Dielectric Barrier Discharges

Underwood, Thomas

This work presents a circuit model for calculating the total energy dissipated into neutral species for pulsed direct current (DC) dielectric barrier discharge (DBD) plasmas. Based on experimental observations, it is assumed that nanosecond pulsed DBDs, which have been proposed for aerodynamic flow control, can be approximated by the two independent regions of a homogeneous electric field. An equivalent circuit model is developed for the homogeneous region near the exposed electrode, i.e., the ―hot spot," based on a combination of a resistor, capacitors, and a Zener diode. Instead of fitting the resistance to an experimental data set, a formula is established for approximating the resistance by modeling a plasma as a conductor with DC voltage applied to it. Various assumptions are then applied to the governing Boltzmann kinetic energy equation to approximate electrical conductivity values for weakly ionized plasmas. The model is compared with experimental data sets of the total power dissipated by a plasma to validate its accuracy.

An Alternative Protein Expression Host for Improved Selection and Analysis of Isolated Synthetic Recognition Elements

Val-Addo, Irene

Bacillus anthracis is a gram-positive, spore-forming bacteria that secretes the three proteins associated with the anthrax infection, protective antigen (PA), edema factor, and lethal factor. The presence of PA is indicative of a possible toxin formation and can be targeted against for detection of *B. anthracis*. Peptide molecular recognition elements (MRE) are currently being studied as an antibody alternative for more improved sensing of proteins like PA. Assays for biological molecules often require the use of multiple recognition elements in a sandwich assay approach. To facilitate the isolation of multiple, unique protein domain recognition elements, a method to produce large, stable, and natively folded proteins is critical. The genes for the full-length PA and its subunit domains were previously cloned and expressed in BL-21 (DE3) *E. coli* cells, but produced insoluble inclusion bodies. To combat this obstacle, a new expression system featuring a *Bacillus megaterium* host was used. *B. megaterium* is within the same genus as the *B. anthracis* bacteria responsible for secreting PA and should allow production of soluble PA proteins.

Multi-body Dynamics Simulation Analysis of Flapping Wing

Valdez, Pierre E.

Multi-Body Dynamics (MBDyn) open source software is used to model flapping wing configurations and simulate simple flapping wing excitations. The wing configurations varied from rectangular wings to locust, balsa, and *Drosphilia* with zero, one, and two spars. Wing tip displacements, rotations, and velocities were measured. These results are compared to experimental results from wings designed by other student in the lab to validate the model and aid in the effort of experimental analysis. The objective is to build a preliminary analysis tool for the Vehicle Technology Directorate (VTD) for applications on flapping wing micro-aerial vehicles (FWMAVs). These MAVs are driven by the most advanced technologies and have great potential to aid the Soldier in a number of scenarios. The ultimate goal is to develop a preliminary optimization space environment that will help to determine the most convenient wing configuration for a given set of requirements. This paper describes the motivation and background of FWMAV's design and the details of the simulation model developed.

Development of a Fin Retention Device for the Flight Controlled Mortar

Valledor, Christian

The active control systems being used in new ‑smart" munitions often require greater aerodynamic stability to properly operate. In the case of the Flight Controlled Mortar (FCM), this stability is provided by a set of super-caliber, spring-loaded, deployable fins that must be stowed prior to launch. For the testing and evaluation process, the FCM tail fins were secured using a single strand of thin Kevlar string. In an attempt to produce a more rugged tactical solution, research and development into alternative Fin Retention Devices (FRDs) was initiated at the start of the summer. After a thorough review of existing FRDs, I determined that a custom solution was needed to fulfill the needs of FCM. Using an iterative design process, concepts were modeled using SolidWorks, and physical prototypes were produced. Based on the analysis of these prototypes, further changes have been identified for ongoing revision. I believe that at the end of this project, a tactical FRD will be produced for testing and evaluation, and may one day be used for the FCM or similar systems employing folding fins.

Computational Modeling of Traumatic Brain Injury in Organotypic Hippocampal Slices

Vogel III, Edward

In both military and civilian life, traumatic brain injury (TBI) has had a noticeable impact. Within the military, serious head trauma resulting from exposure to high-rate blast pressures in the field can lead to serious mental incapacitations, such as memory loss, amnesia and/or physical disorientation. These brain functions have proven to be connected to the hippocampus. Current research on high-rate injury mechanics of the hippocampus has focused on developing injury models or observing biophysiological responses following injury. There has yet to be a serious effort to computationally model this injury. In collaboration with Dr. Barclay Morrison of Columbia University (co-principal investigator [PI] on an U.S. Army Research Office Multi-University Research Initiative, ―Blast Induced Thresholds for Neuronal Networks"), we are attempting to address this need by computationally recreating Morrison's experimental setup, involving experimental injury of hippocampal slices, in order to validate and better understand the injury response of the hippocampus. In preliminary simulations, we have been able to reproduce the experimental setup. As more simulations are completed and data are collected, the mechanical injury response of the hippocampal slices can be recorded and analyzed. Adding a computational component to the current experimental research on hippocampal injury will help researchers gain a better understanding of blast-induce brain injury mechanisms.

Brain Computer Interaction Technology to Enhance Responses to Auditory Communications

Vogel, Mallory

A Brain Computer Interaction Technology (BCIT) is a system that integrates and adapts to the user's brain state and incorporates this change into the function of the system. BCITs are intended to improve the efficiency of user-system interactions by using the human brain's capabilities. This project proposes a BCIT to assist vehicle commanders in a mobile environment where they have many concurrent tasks at one time. The task relevant to this BCIT is the user pressing a button on a touch screen after hearing a specific audio communication. The BCIT would classify the task-relevant neural signal; subsequently, the buttons on the touch screen monitor would increase in size. The design incorporates three MATLAB software packages: BCILAB, Psychtoolbox, and the Parallel Computing Toolbox. The project also requires the creation of an experimental design to test the machine learning algorithm of the BCIT for its accuracy in classifying task-specific neural signals to the proper brain state. The subject is given two communication types that require no response and one that does. This paper provides the framework for prototype development and planned testing of the task-relevant BCIT.

Visual Saliency for Opportunistic Exploration

Warnell, Garrett

This work explores the use of visual saliency methods for camera-equipped mobile robots in order to achieve autonomous battlespace environment exploration. Currently completed work demonstrates the feasibility of saliency-based exploration methods to guide ground-based robots to information-rich areas of an environment. This is accomplished using existing saliency methods and the formulation of a saliency ring, which is used to convert omnidirectional visual saliency information into information associated with various directions. Such information can be used to guide existing robot exploration and motion planning methods. To this end, a prototypical system using an iRobot PackBot and a Point Grey Ladybug 2 omnidirectional camera was constructed. Ongoing work investigates improving existing visual saliency methods and the exploration methods that use the information they generate.

Overview of the Stryker Double-V Hull Live-fire Test and Evaluation Program Crew-casualty Assessment

Weaver, Kate

This paper documents the crew-casualty assessment and analysis that the Warfighter Survivability Branch (WSB) of the U.S. Army Research Laboratory's (ARL) Survivability/Lethality Analysis Directorate (SLAD) provided to the Stryker Double-V Hull (DVH) program. The objective of the Stryker DVH live-fire Test and Evaluation (LFT&E) program is to support a comprehensive evaluation and comparison of the crew survivability afforded by DVH platforms, and compare the survivability of DVH platforms against Stryker baseline vehicles with Operation Enduring Freedom kits. This LFT&E program is meant to determine whether or not the Stryker DVH provides protection to personnel that is at least as good as that afforded by the baseline Stryker. WSB analyzes crew-survivability data and provides technical advice to the LFT&E Integrated Product Team and live-fire evaluators, and contributes to the ARL/SLAD vehicle survivability and vulnerability assessments. WSB performed crew-casualty assessments for all DVH events, as well as comparisons between crew results for comparable events, when appropriate. The primary injury types for which we assessed DVH crew vulnerability were those caused by blast-induced acceleration and overpressure created by underbody threats detonated at various locations, and penetrating injuries created by shaped-charge and explosively formed penetrator (EFP) threats.

Development and Integration of a Current/Power Monitor for Meso-scale Autonomous Systems

Wenger, Kevin

Measuring power consumption is critical to the performance of unmanned systems. In some systems where wireless energy transfer is provided through inductive coupling, it may be necessary for successful operation. In such wireless transfer systems, the power transfer is often dynamic and requires monitoring to stabilize the system. There are a number of ways to measure power consumption, the strongest being a direct measurement with a bench-top instrument. However, in real-world applications, bench-top supplies are too bulky and unwieldy. For the application of wireless energy transfer, the intended benefit of making energy transfer wireless is to reduce the weight that batteries contribute. Tethering the device to a bulky bench-top power supply defeats the purpose of wireless energy transfer, so a small portable solution is required. In this paper, I will outline the integration of a small (SOT-8 surface mount package), highly accurate (10-μV resolution) current/power measurement IC with a wireless energy transfer system on board a piezoelectric transducer (PZT) actuator driven flapping wing device.

Direct Write of Copper Micro-circuitry by Capillary Focusing

Wienhold, Erik

This work describes the development of a direct write system for the creation of copper (Cu) micro-circuitry by way of capillary focusing. Cu was selected as a baseline test to be deposited onto a polymer ceramic base dielectric. The Department of Defense is investigating an electronic package that can withstand the high G-forces associated with projectile launch, which can be created using Cu that has been impact-fused onto a polymer ceramic base. The system will be based on cold spray technology, in that Cu particles are injected into a high pressure helium (He) gas line and exit through a nozzle to accelerate the particles to velocities necessary for impingement. Since this is an additive process, it does not require chemical etching as used in conventional circuit board fabrication. In previous experiments that used cold spray to apply Cu to silicon carbide, the deposited Cu had measured conductivity close to pure wrought Cu and had high bond strength. However, this system uses a 125-micron capillary tube that enables fine deposit resolution. The system will be mounted onto a computer numerical control (CNC) machine that will be controlled by computer-based software, ensuring accuracy and repeatability in the creation of circuitry patterns.

Genetically Programming Biological Templates of Electrode Material for Improved Performance in Lithium Ion Technologies

Wikner, Emily

Biological researches have recently created a genetically engineered M13 bacteriophage that acts as a template for nanostructured electrodes in lithium ion technologies. When bonded to single-walled carbon nanotubes by the engineered pVIII proteins (EFEs) and to aluminum surfaces through the engineered pIII proteins, the phage acts as a bifunctional nanowire that promotes fast charge transfer during the Li ion battery operation. In this work, the structure of the phage is further engineered by "reprogramming" the single-strand DNA codes in M13 bacteriophage, so that the five copies of the pIII protein are changed from histidine heptamer (H7) to histidine dodecamer (H12) for higher affinity toward aluminum surface, which is a common surface used in all Li ion batteries. A higher-power density is thus expected from electrode materials constructed on such new virus templates.

An EFE H7 vector is double-digested with restrictive enzymes. Following a series of purification protocols, including gel-electrophoresis, YM-30 desalting, and dephosphorylation, an oligonucleotide that codes for the synthesis of H12 was integrated to create a recombinant DNA (EFE-H12). Using an electroporation, the new DNA is used to infect XL-blue electro-competent bacteria so that new clones of M13 viruses constructed with EFE-H12 can be produced. Following the successful virus production and DNA-sequence confirmation, we will amplify the new clone of the M13 virus in large scale so that multifunctional nanostructured electrode materials can be synthesized. When used in Li ion batteries, the electrode materials built on the new virus clone with a longer chain of histidine will be expected to improve the charge-transfer rates across and through these nanowires.

Statistical Methods for Analyzing Marksmanship

Wojciechowski, Matthew

Studies involving marksmanship performance are often carried out by the Dismounted Warrior Branch and other groups within the U.S. Army Research Laboratory. Once data has been collected within the desired parameters, the researchers must consider how it will be analyzed. Upon reviewing various technical reports and other sources, we inventoried and outlined all of the methods and approaches that can be used to analyze marksmanship. We also evaluated and reported on the advantages and disadvantages of each method. An important distinction was made between marksmanship accuracy, which is the measurement of proximity to the point of aim, and marksmanship precision, which is the measurement of dispersion or ―shot group tightness.‖ To better understand and explain the different methods of analysis, we used a set of data to simulate some of the statistical methods. This inventory of different statistical tools that can be used to analyze marksmanship will be used to determine which tools will be used in upcoming research.

Robust Image Registration through Convolutional Neural Networks with Feedback from Segmentation and Motion Estimation

Won, Stephen

Image registration for a frame sequence is critical in moving-object tracking and super-resolution applications. Current methods of motion detection and estimation perform poorly in low signal-to-noise situations. We propose a new method that combines the current methods with a machine learning technique, the convolutional neural network (CNN), to improve registration accuracy with a reasonable training time. The CNN is trained using the areas identified by motion detection from the initial frames to address conditions specific to the current image sequence. To make the CNN more robust against image variations, transformations of rotation, shift, and scale are applied to each training image. After initial training, motion segmentation and estimation is performed on the image sequence to provide an area for a sliding window to parse image patches through the CNN to accurately estimate the location of the moving object. Once the object is found from the initial frames, the results are used to update the weights and biases of the CNN for later images in the sequence. Both gross and sub-pixel shift estimation accuracy results from a set of real world images with moving cars and people will be provided.

Rechargeable Lithium Ion Battery Power Source for High Energy Fiber Laser

Yang, Zhi

High power lasers are not found on the field of operation due to their high power requirements. They are not considered mobile units, but, instead, are attached to some stationary power supply. With the push for electric vehicles from the auto industry, battery technology now has progressed to a level that can satisfy their power requirements. We intend to show that with off-the-shelf batteries, these high power lasers can run for prolonged periods of time.

Several criteria of the battery will be used to judge if it is suitable for the laser. Some examples would be energy density, power density, weight, safety, charge time, performance (extreme temperature), and cost. At this stage, the energy density and power density of the battery will be the only criteria considered. A battery pack with a capacity of about 3 kW-h is to be connected to a laser diode driver from Direct Energy Inc. First, the laser diode driver will be connected to a dummy load to test for any abnormality that may damage the laser diode. The laser will then run continuously and it is expected that the batteries be able to drive the laser for a minimum 10 h.

Trial-to-Trial Variations in Susceptibility to Cross-Sensory Bias

Yu, Alfred

The ventriloquism aftereffect is a perceptual illusion in which auditory localization is biased by repeated exposure to auditory and visual stimuli with spatially discrepant locations. When observers perform an auditory localization task with a concurrent visual distractor, the latter tends to ―capture" the auditory stimulus, leading to bias in the estimate of the sound's location. Even a small audio-visual discrepancy can lead to sensory recalibration on a moment-to-moment basis, with the present performance being influenced by the discrepancy on previous occurrences. This study found that such an effect is modulated by awareness of a cross-sensory discrepancy on the previous presentation of stimuli; a decreased level of bias was observed when the auditory and visual stimuli on the previous trial were judged to be spatially distinct. The results have implications for the design of indirect vision systems to increase situational awareness in closed-hatch operations.

Polarization-Enhanced Tunnel Junctions in Tandem Solar Cells

Zhou, Shuai

Gallium nitride (GaN)-and indium nitride (InN)-based heterostructures have the potential to reach much higher solar energy conversion efficiencies than currently available solar cells. By using the mechanism of quantum barrier tunneling in a p-down tandem structure, and the desirable band gap properties of GaN and InN, one can capture much of the solar spectrum and provide a low-resistance current pathway for efficient energy harvesting applications. This paper seeks to demonstrate quantum barrier tunneling by characterizing I-V conduction behaviors on diodes fabricated on GaN/aluminum nitride (AlN) heterostructures. By varying the AlN tunnel junction layer thickness, we found that a layer of thickness, 2.5 nm, showed the highest reverse current density at low reverse bias. Although this does not directly support the signature of interband tunneling, it does show that an AlN thickness closer to the critical thickness (2.8 nm) will more likely induce tunneling. This will allow one to further investigate other characteristics, such as varying doping levels of the GaN layers, as well as determining the exact thickness of the AlN with transmission electron microscopy (TEM) to further increase the probability of interband tunneling.

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